This document is a courtesy English translation of the Final Report on the fatal air accident to the RRJ-95B RA-89098 aircraft, occurred on May 5, 2019 at 15:30 UTC at Sheremetyevo aerodrome, the Moscow region, Russian Federation.

The document has been translated as accurately as possible to facilitate the understanding of the Final Report for the non-Russian speakers. The use of this courtesy translation for any other purposes than the prevention of future accidents could lead to erroneous interpretations.

In case of any inconsistency or misunderstanding, the original text in Russian shall be used as the work of reference.

INTERSTATE AVIATION COMMITTEE

FINAL REPORT
ON THE RESULTS OF THE AIR ACCIDENT INVESTIGATION

Type of occurrence	Fatal accident
Type of aircraft	RRJ-95 (RRJ-95B model) airplane
Nationality and registration marks	RA-89098
Owner	VEB Leasing, JSC
Operator	Aeroflot, PJSC
Aviation authority	FATA
Place of occurrence	Sheremetyevo aerodrome, Moscow region, Russian Federation; reference position: 55°58′06.20″ N, 37°24′07.20″ E
Date and time	May 05, 2019, 18:30 local time (15:30 UTC), daytime

In accordance with the ICAO Standards and Recommended Practices this Report is issued with the sole objective to prevent the air accidents.
It is not the purpose of this Report to apportion blame or liability.
Criminal aspects of the accident are tackled within separate criminal case.

ABBREVIATIONS

7500	– aircraft hijacking (international squawk code)
7600	– radio loss (international squawk code)
7700	– emergency (international squawk code)
A/C (AC)	– Aircraft
A/P (AP)	– autopilot
A/T	– autothrottle
AAIC	– Air Accident Investigation Commission
AAL	– above aerodrome level
AC	– Alternating Current
ACARS	– Aircraft Communications Addressing and Reporting System
ACCREP	– ACCredited REPresentative
ACE	– Actuator Control Electronics
ACP	– Audio Control Panel
ADC	– Air Data Computer
ADIRU	– Air Data Inertial Reference Unit
ADS	– Air Data System
AFCS	– automatic flight control system
AFE	– above field elevation
AFL	– Aeroflot
AFM	– Airplane Flight Manual
AGL	– Above Ground Level
AIP	– Aeronautical Information Publication
AMM	– Aircraft Maintenance Manual
AMS	– audio management system
AOA	– angle of attack
AOC	– air operator certificate
APC	– Aircraft-Pilot Coupling, see PIO
APU	– auxiliary power unit
AR	– Aviation Regulations
AR-21	– Aviation Regulations Part 21 «Aircraft Certification Procedures»
AR-25	– Aviation Regulations Part 25 «Airworthiness Standards: Transport Category Airplanes»

ARINC – Aeronautical Radio Incorporated, the standard file format for aircraft navigation data
ARP – aerodrome reference point
ASL – above sea level
ATA – Air Transport Association
ATC – air traffic control
ATIS – Automatic Terminal Information Service
ATM – air traffic management
ATPL – airline transport pilot's license
ATS – air traffic service
B-RNAV – Basic Area Navigation
BAT – Battery
BEA – Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, France
BFU – Bundesstelle für Flugunfalluntersuchung, Germany
CAS – Calibrated Airspeed / Crew Alerting System
CAT – category
CEH – complex electronic hardware
CFA – chief flight attendant
CG – center of gravity
Ch. – Channel
CJSC – closed joint-stock company
CM1/CM2 – crewmember 1/crewmember 2
CP – control panel
CPL – commercial pilot's license
CRI – Certification Review Item
CRM – Crew Resource Management
CS – Certification Specifications, EASA
CVR – Cockpit Voice Recorder
DA – decision altitude
DAR – digital aircraft condition monitoring system recorder
DC – Direct Current
DCV – Directional Control Valve
DECU – digital engine control unit

DH – decision height

Doc – Document

DY – DaY

E – eastern longitude

EASA – European Aviation Safety Agency

ECU[1] – Engine Control Unit

EFIS – Electronic Flight Instrument System

EIU – Engine Interface Unit[2]

ENG – ENGine

ENG MASTER – Engine Master switch

EOSU – Engine Overspeed Unit

ESS – Essential

EWD – Engine/Warning Display

F/A – flight attendant

F/O – first officer

FAA – Federal Aviation Administration, USA

FAF – final approach fix

FAP – final approach point

FAR – Federal Aviation Regulations

FAR-60 – Federal Aviation Regulations # 60 «The provision of meteorological information to support the air operations»

FAR-121 – Federal Aviation Regulations Part 121 «Operating Requirements: Domestic, Flag, and Supplemental Operations»

FAR-128 – Federal Aviation Regulations # 128 «The preparation and performance of the civil aviation flights in the Russian Federation»

FAR-136 – Federal Aviation Regulations # 136 «The federal aviation regulations to the air operations in the Russian Federation airspace»

FAR-147 – Federal Aviation Regulations # 147 «The requirements to the aircraft crewmembers, the aircraft maintenance personnel and the air operations support employees (the flight dispatchers)

[1] Through the subject Report the DECU and ECU abbreviations are applied as synonyms.
[2] It is this interpretation of the indicated abbreviation that the English version of FCOM read at the time of the air accident. Now it stands for Electronic Interface Unit.

FAR-246	–	Federal Aviation Regulations # 246 «The requirements to legal entities, individual entrepreneurs, engaged in the commercial air transport. The form and procedure for issuing the document, confirming compliance of legal entities, individual entrepreneurs, engaged in the commercial air transport, with the Federal Aviation Regulations requirements»
FAR-293	–	Federal Aviation Regulations # 293 «The air traffic management in the Russian Federation»
FAR ME CA-2002	–	Federal Aviation Regulations «Medical examination of the flight and ATC personnel, flight attendants, pilot students, and entrants to the educational institutions of civil aviation» of the year 2002
FATA	–	Federal Air Transport Agency
FBWCS	–	Fly-by-Wire Control System
FCOM	–	Flight Crew Operating Manual
FCS	–	Flight Control System
FCTM	–	Flight Crew Training Manual
FCTP	–	flight crew training program
FCTS	–	Flight Crew Training Standards
FD	–	flight director
FDM	–	flight data monitoring
FDR	–	Flight Data Recorder
FFS	–	Full Flight Simulator
FH	–	Flight Hours
FIR	–	flight information region
FL	–	Flight Level
FLAPS	–	Flap/Slat Selector Lever
FMA	–	flight mode annunciator
FMS	–	Flight Management System
FMU	–	Fuel Metering Unit
FOD	–	foreign object damage
FPC	–	Fire Protection Computer
FR	–	frame
FQIC	–	Fuel Quantity Indication Computer
FSCU	–	Fuel System Control Unit
FSEI HPE	–	federal state educational institution of higher professional education

FSFI	– federal state-funded institution
FSFEI HE	– federal state-funded educational institution of higher education
FSFEI HPE	– federal state-funded educational institution of higher professional education
FSUE	– federal state unitary enterprise
ft.	– feet
ft/min, FPM	– feet per minute
G	– load factor
G/A	– go-around
GCU	– Generator Control Unit
H24	– twenty-four hour operation
H_{target}	– target altitude
hPa	– hectopascals
HPSOV	– high-pressure shutoff valve
HQC	– higher qualification commission
hr	– hour
hrs	– hours
IAC	– Interstate Aviation Committee
IAC AR	– Interstate Aviation Committee Aviation Register
IAS	– indicated airspeed
ICAO	– International Civil Aviation Organization
ICU	– Isolation Control Unit
IDLE	– idle (engine power rating)
IFDMU	– Integrated Flight Data Management Unit
IFR	– Instrument Flight Rules
illeg.	– illegible
ILS	– Instrument Landing System
INS	– Inertial Navigation System
INV	– Inverter
IRS	– Inertial Reference System
ISV	– isolation solenoid valve
JSC	– joint-stock company
kg	– kilogram
kgf	– kilogram-force

kN	– kilonewton (unit of force)
kt	– knot (unit of speed)
L	– Left
LG	– landing gear
LLC	– limited liability company
LOFT	– Line Oriented Flight Training
m	– meters
MAC	– mean aerodynamic chord
MACE	– Motor and Actuator Control Electronics
MAYDAY	– the international distress signal in voice-procedure radio communications
MAX	– maximum
MEL	– Minimum Equipment List
METAR	– METeorological Aerodrome Report
MFD	– Multifunctional Display
MFEC	– medical flight-expert commission
min	– minute(s)
MLG	– main landing gear
MMPI	– Minnesota Multiphasic Personality Inventory
MOE	– Maintenance Organization Exposition
MP	– Maintenance Program
MSFI	– municipal state-funded institution
N_1	– low pressure compressor speed
ND	– navigation display
nm	– nautical mile
NSEI FPE	– non-state educational institution of further professional education
NSEPI SPE	– non-state educational private institution of secondary professional education
NOTAM	– Notice to Airmen
NPA	– non-precision approach
NTO	– Normal Takeoff
NTSB	– National Transportation Safety Board, USA
NVM	– non-volatile memory
OFF	– not operating because of not being switched on
OFP	– Operational Flight Plan

ON	– something is operating or starting to operate
P-RNAV	– Precision-Area Navigation
p/n (PNR)	– part number
PAN–PAN	– the international urgency signal in voice-procedure radio communications
Pamb	– ambient pressure at the flight altitude
PACIS	– passenger address and communication intercom system
PBE	– Protective Breathing Equipment
PCMCIA	– Personal Computer Memory Card International Association
PF	– pilot flying
PFCU	– Primary Flight Control Unit
PFD	– Primary Flight Display
PIO	– Pilot-Induced Oscillations[3]
PL	– Primary Lock
PLL	– Primary Lock Lower stow/lock switch
PLU	– Primary Lock Upper stow/lock switch
PMA	– permanent magnet alternator
PMMA	– polymethyl methacrylate
PNF	– pilot non flying
PPI	– plan position indicator
PSE	– primary structural element
PT	– total pressure
PTT	– Push-To-Talk
PVC	– polyvinyl chloride
PWS	– Predictive Windshear System
QFE	– atmospheric pressure at runway threshold
QNE	– the barometric pressure used for the standard altimeter setting
QNH	– atmospheric pressure adjusted to mean sea level
QRH	– Quick Reference Handbook
R	– Right
REV	– (thrust) reverser
RHQC	– Regional Higher Qualification Commission

[3] The Pilot-Involved Oscillations designation is applied as well.

RNAV – Area Navigation, when designated with a number, it indicates the lateral navigation precision in nautical miles, with the 0.95 probability the aircraft shall be flown within the specified limits

RNP – Required Navigation Performance, when designated with a number, it indicates the lateral navigation precision in nautical miles, with the 0.95 probability the aircraft shall be flown within the specified limits

RMS – root mean square

Roshydromet – Federal Service of Russia on Hydrometeorology and Monitoring of the Environment

RSU – Rate Sensor Unit

RVDT – Rotary Variable Differential Transformer

RVR – runway visual range

RVSM – Reduced Vertical Separation Minima

RWS – Reactive Windshear System

SBITE – system built-in test equipment

SCAC – Sukhoi Civil Aircraft

SID – Standard Instrument Departure

SIGMET – SIGnificant METeorological Information, the information issued by a meteorological watch office concerning the occurrence or expected occurrence of specified en-route weather phenomena which may affect the aircraft operations safety

SMM – Safety Management Manual

SOP – Standard Operating Procedures

SOV – shutoff valve

SPECI – SPECIal weather report

SS – sidestick

STAR – Standard Arrival Route

SW – Switch

t – time

TAF – Terminal Aerodrome Forecast

TAT – Total Air Temperature

TAWS – Terrain Avoidance and Warning System

TCAS – Traffic Collision Avoidance System

TCDS – Type Certificate Data Sheet

TDWR	– Terminal Doppler Weather Radar
TL	– thrust lever/Tertiary Lock
TLA	– Thrust Lever Angle
TLL	– Tertiary Lock Left
TO/GA	– Takeoff / Go-Around engine power rating
T/R (TR)	– Thrust Reverser
TRU	– Transformer Rectifier Unit
UTC	– Coordinated Universal Time
V_1	– takeoff decision speed
V_2	– takeoff safety speed
V_R	– rotation speed
VDR	– VHF Data Radio
VHF	– Very High Frequency
VSWR	– Voltage Standing Wave Ratio
W/S (WS)	– windshear
W/S AHEAD	– windshear ahead
ZFTT	– Zero Flight Time Training
δsl	– slats deflection angle
δfl	– flaps deflection angle
Δh	– ground surface elevation

SYNOPSIS

On May 5, 2019 at 18:30 local time (15:30 UTC)[4], in the progress of landing on the Sheremetyevo aerodrome RWY 24L there occurred the fatal air accident to the Aeroflot, PJSC RRJ-95B RA-89098 aircraft. The aircraft was performing the SU-1492/AFL1492[5] scheduled passenger flight en route from Sheremetyevo airport (UUEE) to Murmansk airport (ULMM). In the sixth minute of the flight after the aircraft exposure to the atmospheric electricity, the crew made the decision to return to Sheremetyevo airport.

There were 2 flight crewmembers, 3 cabin crewmembers and 73 passengers aboard the aircraft. As far as the passengers are concerned, 72 of them were the citizens of Russian Federation, 1 passenger had USA citizenship, and the crewmembers were the Russian citizens. As the outcome of several touchdowns with a considerable vertical acceleration and the erupted ground fire the aircraft sustained significant damage. As the result of the air accident 1 cabin crewmember and 40 passengers (39 having been the Russian Federation citizens, 1 of the USA citizenship) were fatally injured, 4 crewmembers and 5 passengers got serious injuries, 28 passengers sustained minor injuries.

IAC was notified about the accident at 15:53 on May 05, 2019.

The investigation team, appointed by the IAC AAIC Chairman Orders # 8/909-p of May 05, 2019 and # 8/910-p of May 14, 2019, conducted the investigation of the air accident.

In compliance to ICAO Annex 13 to the Convention on international civil aviation «Aircraft Accident and Incident Investigation» the notifications about the accident were forwarded to BFU (Germany) being the competent authority of the flight control system State of Design and State of Manufacture; NTSB (USA) being the competent authority of the State of Design and State of Manufacture of the number of the aircraft components, as well as the State, having suffered fatality to its citizen; BEA (France) being the competent authority of the State of Design and State of Manufacture of the engines, as well as of the number of the aircraft components. The indicated States have appointed the ACCREPs to participate in the investigation.

The representatives of FATA, the aircraft designer (SCAC, JSC[6]), Aeroflot, PJSC, State ATM Corporation, FSUE, the Gromov Flight Research Institute, JSC, Sheremetyevo International Airport, JSC, S7 Engineering, LLC, Roshydromet Head Aeronautical Meteorological Center, FSFI and other organizations assisted to the investigation.

The initial actions at the air accident scene (the passengers' evacuation, the guard of the place of occurrence) were undertaken by the EMERCOM, the Sheremetyevo International Airport,

[4] Hereinafter, unless otherwise stated, UTC is indicated, the local time is UTC + 3 hrs.
[5] Hereinafter through the text these designators are used interchangeably.
[6] The aircraft designer is currently Yakovlev, PJSC.

JSC, and Aeroflot, PJSC personnel. In drawing up the Report the data, submitted by the mentioned organizations, were taken into account.

The investigation was opened on May 5, 2019.

The investigation was closed on March 10, 2025.

For the purposes of *«the investigation of the causes of the fatal accident to the Aeroflot – Russian Airlines, PJSC Superjet RRJ-95B aircraft (the RA-89098 tail number), occurred on May 05, 2019 in the Moscow region, assistance to aircraft accident victims and the families of the deceased, as well as the assistance in eliminating consequences of the subject fatal accident»*[7] by the Russian Federation Prime Minister order # 890-p of May 6, 2019 the government commission was set up, chaired by the Russian Minister of Transport.

The pretrial proceedings have been conducted by the Russian Federation Investigative Committee General Directorate for Major Investigations.

[7] Hereinafter, unless otherwise stated, as for the quotes in italics the author's wording is retained.

1. Factual information

1.1. History of flight

On May 05, 2019 the Aeroflot, PJSC flight crew out of the PIC and F/O was performing the SU-1492 scheduled passenger flight en route from Sheremetyevo airport (UUEE) to Murmansk airport (ULMM) aboard the RRJ-95B RA-89098 aircraft. 3 cabin crew members were also indicated in the flight assignment.

The crew arrived to the airport at about 2 hrs prior to departure. After having undergone the mandatory preflight procedures (the medical check, briefing etc) the crew took up their duties at the flight deck.

The passengers boarding was proceeded through the left front door. By 14:40 all the passenger and baggage holds doors had been closed.

At 14:45:30 the ATC officer approved the engines start up.

At 14:50:15 the crew initiated taxiing.

At 14:57:20, after having been issued the clearance, the crew lined up at RWY 24C, where held the position for about 5 min.

At 15:02:23 the ATC officer issued clearance for takeoff.

After takeoff at 15:03:36 at the QNH altitude of 1250 ft. (380 m), the radio altitude of 690 ft. (210 m) and the IAS[8] of 160 kt (296 km/h) the A/P was engaged.

At 15:03:56 the Sheremetyevo Radar ATC officer cleared the climb to the QFE 1200 m altitude as per the KN 24E SID.

At 15:05:18 the Sheremetyevo Radar ATC officer instructed the crew to climb to FL60.

At 15:05:33 the crew set QNE of 760 mm of mercury/1013 hPa.

At 15:06:57 the Sheremetyevo Radar ATC officer instructed the crew to climb to FL70 and contact the Approach ATC.

After having initiated the contact with the Approach ATC officer the crew was instructed to climb to FL90.

Between 15:07:30 and 15:07:33 the dialogue as follows was recorded in the crew: PIC: *«It is going to bump now»,* – F/O: *«Crap»,* – PIC: *«That's all right».*

At 15:07:34 the Approach ATC officer instructed to climb to FL100.

At 15:08:03 the Approach ATC officer instructed to climb to FL110. After the F/O confirmed this instruction the CVR recorded the noise effect of 1.5 sec. duration, starting from 15:08:09.7. Most probably at that point the aircraft encountered the atmospheric electricity strike.

[8] Hereinafter when referring to the aircraft flight speed the IAS term or just the speed word is used. At that the numeric values are given in accordance with the FDR record, which ensures recording subject to the position error (that is actually the calibrated airspeed/CAS that is recorded).

At 15:08:11.9 the A/P was disconnected, accompanied by the respective sound warning, as well as by the reversion of the FBWCS to DIRECT MODE with the DIRECT *MODE. DIRECT MODE* synthetic voice triggered. The A/T continued to operate. The aircraft at that moment was proceeding flight in right roll of about 20°, passing FL89 (2700 m) in climb.

From 15:08:16 the manual control from the left duty station was initiated. The aircraft was proceeding the right turn as per the KN 24E SID and climb.

At 15:08:47 the A/T was disconnected with the «override» (the TLA was changed from ~ 29.5° to ~ 19°). The further flight was continued by a manual control at the FBWCS DIRECT MODE.

At 15:09:17 the aircraft was pulled out of the right turn to a heading of about 60°.

After a short discussion in the crew the PIC made the decision to return to the departure aerodrome and commanded the F/O to declare PAN–PAN (an urgency signal). After several unsuccessful attempts to establish contact with the ATC officer at the operating frequency with the use of VDR 1 (this radio unit was used for communications from the beginning of the flight), at 15:09:32, after discussion, the 7600 squawk code was set by the crew.

At 15:09:35, the radio communication was resumed on the emergency frequency (121.5 MHz) with the use of VDR 2. After radio communication was restored, at 15:09:39, the F/O reported to the Approach ATC officer: *«Moscow Approach, and we request return 14 -92, radio contact lost and aircraft in DIRECT MODE».* The ATC officer instructed to descend to FL80. The maximum altitude the aircraft reached was 10600 ft. (3230 m) QNE. The crew replied: *«Aeroflot 14-92, heading 0-57, descending 8-0»*. The flight further on until glideslope interception was proceeded by vectoring.

At 15:24:38 to the ATC request on the approach type for landing the crew advised that it would be an ILS approach.

At 15:26:30 the crew set the 7700 squawk code. The reason for setting was not reported to the ATC.

At 15:27:20 the glideslope descent was initiated.

At 15:27:51 the ATC officer relayed the weather information to the crew and cleared landing: *«Aeroflot 14-92 surface wind 160 7, gusts 10 meters per second, runway 24L, cleared for landing».*

At 15:30:00 at the distance of ≈ 900 m off the RWY entry threshold and at IAS of 158 kt (293 km/h) there occurred the RWY first touchdown. The touchdown occurred practically on «three points», with the vertical acceleration[9] of not less than 2.55G with a subsequent aircraft

[9] Hereinafter the vertical acceleration is referred to as the values, recorded by FDR, that is at the sensor installation point. As the parameters record is carried out with a certain sampling rate, the actual values could have been higher. To process specific tasks, as for the determination of the acceleration level, applied to in other areas of the airplane, the recorded values were recalculated.

separation/bounce off the RWY. Another touchdown occurred in 2.2 sec. after the first one at the IAS of 155 kt (287 km/h). The touchdown occurred with the advancement on the NLG. Vertical acceleration amounted to not less than 5.85G. There occurred another aircraft bounce off the RWY.

At 15:30:06 at the IAS of 140 kt (258 km/h) the third touchdown occurred with the vertical acceleration of not less than 5G.

As a consequence of hard touchdowns the MLG legs and the airframe structural elements were destroyed with the fuel spillage and the subsequent onset of fire.

Into the further movement of the aircraft there occurred its RWY veering off to the left. At 15:30:38 the airplane stopped. The aircraft stop occurred on the soil between TWY2 and TWY3 at the point with the reference position 55°58′06.20″ N, 37°24′07.20″ E, Δh = 185 m, with true heading ≈ 128°. The distance off the RWY 24L entry threshold amounted to ≈ 2720 m, lateral deviation was about 110 m to the left off the RWY 24L centerline.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	40	0
Serious	4	5	0
Minor/None	0/0	28/0	0/0

1.3. Damage to aircraft

Fig. 1 presents the general view of the aircraft at the accident site.

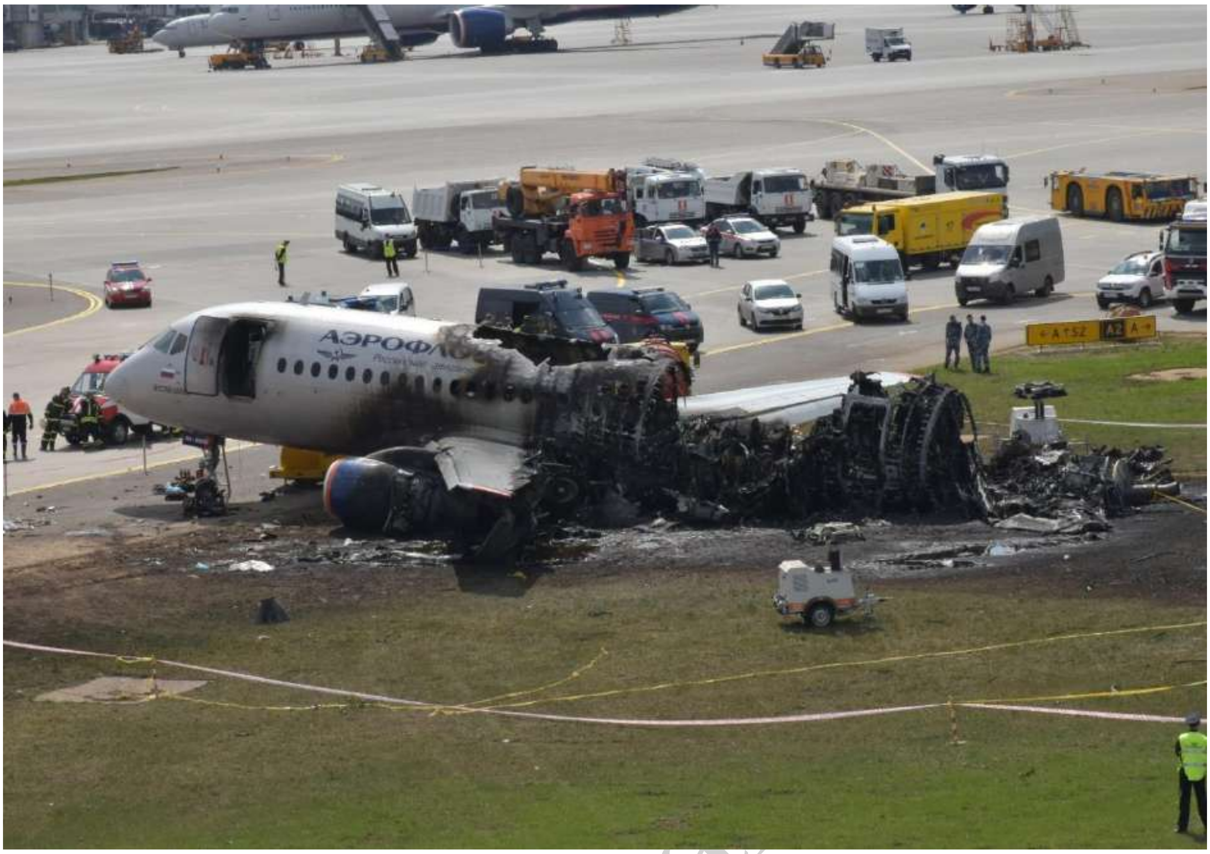


Fig. 1. The RRJ-95B RA-89098 airplane after the air accident

No visible significant structural damage is identified of the F1, F2 fuselage compartments/FR1 – 24 (Fig. 2)[10].

Fig. 2. The post-accident forward fuselage exterior

The F3 and F4 fuselage compartments/FR24 – 51 burnt out completely upwards from the floor level beyond the FR29 and sustained the considerable skin burnout below the floor level (Fig. 3).

[10] See Fig. 42 to understand the fuselage sections layout.

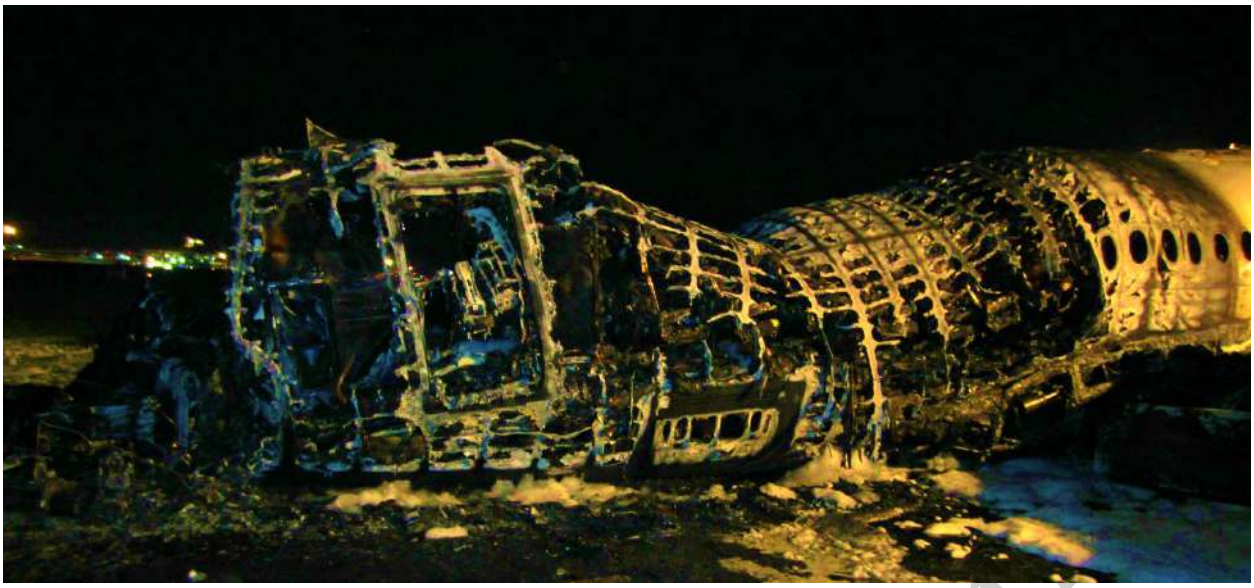


Fig. 3. The post-accident center and rear fuselage exterior

The F5 fuselage compartment is completely burnt out, the elements of the fuselage framework and the assemblies are allocated on the ground surface (Fig. 4).

Fig. 4. The F5 compartment exterior

The F6 compartment is burnt out except for the steel and titanium alloy parts, the survived elements of the fuselage framework and assemblies (Fig. 5) were allocated on the ground surface.

Fig. 5. The F6 compartment elements exterior (the picture was taken at the storage site)

The vertical and horizontal parts of the empennage are burnt out, their survived elements (Fig. 6) were resting on the ground surface.

Fig. 6. The post-accident exterior of the vertical and horizontal parts of the empennage (the picture was taken at the storage site)

The wing panels with the mounted engines are attached to the fuselage. The primary wing damage and its elements condition is as follows:

- the right wing lower skin is burnt out, but for the root segment;
- the aft fairing of the right wing pylon was burnt, the flap fairing is burnt out;

– the right MLG actuating cylinder mounting bracket is separated off the rear spar and rests hanging above the panel box (Fig. 7). After the separation of the right MLG actuating cylinder mounting bracket the hole was formed in the spar web, through which the fuel had been leaked out of the right wing fuel tank (Fig. 8);

Fig. 7. The right MLG actuating cylinder exterior

Fig. 8. The hole in the right wing spar web at the cylinder mounting location (pointed with arrow)

– the destruction of the upper panel, booms and web of the fore spar of the right wing box, adjacent to the pylon hinge fitting exposed to the vertical load by the pylon attachment fittings at the fore spar (Fig. 9 and Fig. 10). These elements are the fuel tanks walls;

Fig. 9. The destruction of the right wing adjacent to ribs 3-4 in between the fuselage and engine pylon

Fig. 10. The destruction of the upper panel and the fore spar of the right wing adjacent to ribs 3-4 in between the fuselage and engine pylon

– the left wing nose lower skin is burnt and deformed;

– the left MLG actuating cylinder mounting bracket is separated off the rear spar and rests hanging above the panel box. The nature of the separation and damage (Fig. 11 and Fig. 12) is similar to the right MLG. The rear spar upper panel, caps and web of the left wing box adjacent to ribs 5-6 sustained damage as well (Fig. 13 and Fig. 14), these elements are the fuel tanks walls;

Fig. 11. The left MLG actuating cylinder exterior

Fig. 12. The hole in the left wing spar web at the actuating cylinder mounting location (pointed with arrow)

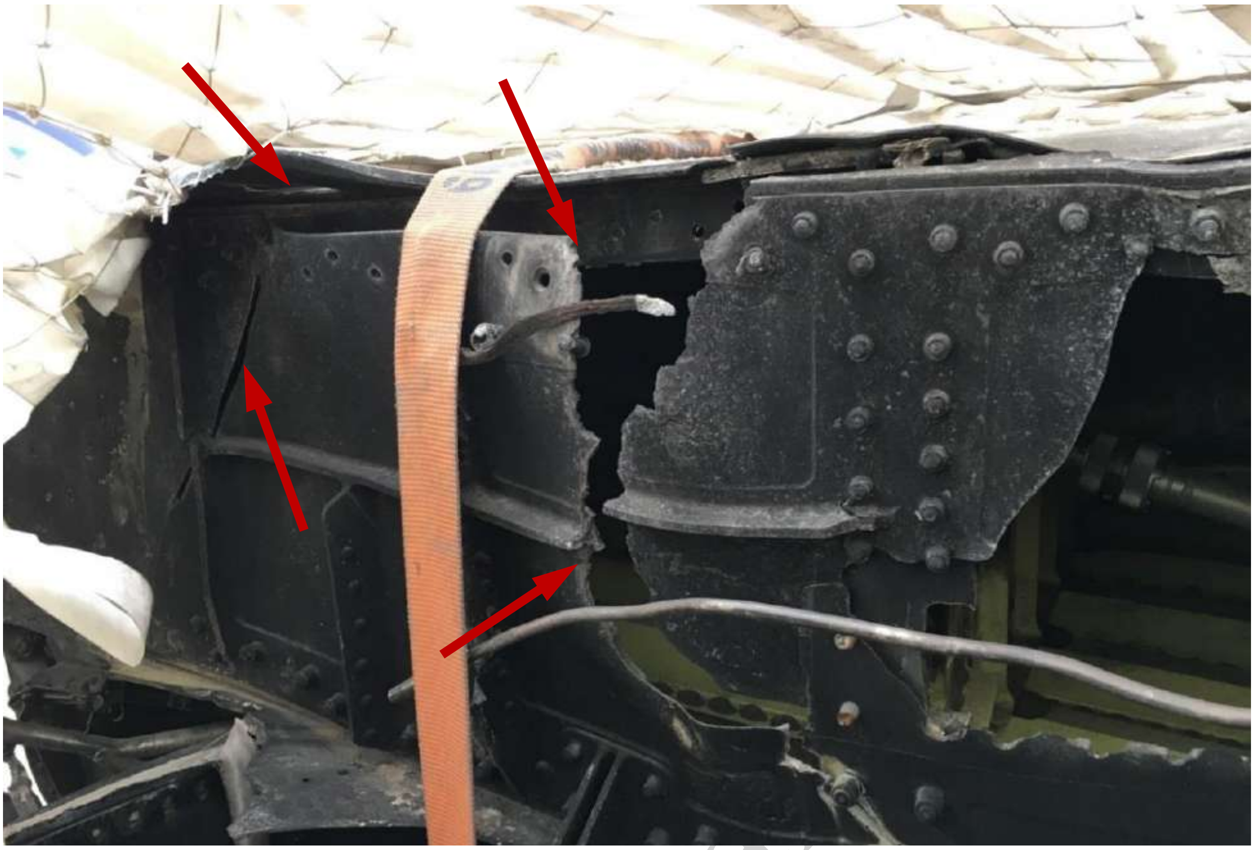


Fig. 13. The destruction of the rear spar of the left wing adjacent to ribs 5-6

Fig. 14. The destruction of the rear spar of the left wing adjacent to ribs 5-6 and the landing gear beam hinge bracket

Doors, access doors, cockpit windows

The right and left FWD doors of the passenger cabin are opened, the escape slides bars are engaged to the mounting brackets of the step bars (Fig. 15).

Fig. 15. The post-accident FWD doors - the left and right ones - exterior

The right aft door of the passenger cabin is missing along with the door support arm. The escape slide bar is engaged to the step bars mounting brackets. The frame, which the door is hinged to, was removed at the emergency response. As per the analysis of photos after the accident the door had been closed. The door with the door support arm was retrieved in the aircraft wreckage.

The left rear door of the passenger cabin is missing (burnt out). The door support arm is in an open position. The escape slide bar was retrieved in the aircraft wreckage on ground.

The rear door of the baggage compartment is closed, severely burnt with the through burnout of the outer skin. The FWD baggage compartment door is closed with no visible damage on it.

The emergency escape access door is opened in the cockpit door. The door has no visible damage.

The right window of the cockpit is opened, the left one of the cockpit is closed.

The rear baggage compartment is partially damaged, but there are no burning or open fire sings observed in the compartment. Traces of soot were revealed on the front wall of the compartment and on the passengers' baggage (Fig. 16). The rear baggage compartment after the accident was accessible through the upper access door that did not sustain any mechanical damage (Fig. 17).

Note: *Each panel of the baggage-cargo compartment is non-flammable and in accordance with the AR-25 item 25.855 (as to the Class C compartments). Each baggage-cargo compartment panel has two tapes, laid on it one after the other around the perimeter – the sealing and the fire-blocking ones, which ensures the protection against fire and smoke propagation outside the baggage-cargo compartment.*

Fig. 16. The passengers’ baggage, having been allocated in the rear baggage compartment subsequent to the accident

Fig. 17. The rear baggage compartment exterior subsequent to the accident

Fuel system

– the fuel pumps are on their standard locations and show traces of exposure to high temperatures;

– the fuel system assemblies are melted, the fuel system valves installed on the wall of the rear spar are on their standard locations;

– into the landing gear bay (the area, having had the most exposure to flames) the twin motor actuator is completely burnt;

– the fuel tanks venting system assemblies are on their standard locations with no mechanical damage observed;

– the fuel feed lines and the APU are decoupled;

– there were no fire traces revealed inside the fuel tanks;

– the F5 compartment fuel system assemblies are inaccessible for inspection due to the complete destruction of the compartment.

Landing gear

– the NLG is in an extended position with no visible damage and no traces of the hydraulic fluid leakage observed;

– the left and right MLG legs are in an extended position and are substantially damaged;

– the MLG harnesses (the electric ones, the hydraulic hoses) are stated to be disintegrated;

– the mechanical damage was stated to the MLG braces and the elements that ensure their fold;

– the right MLG side brace fuse spring is destroyed, its fragment was discovered on the RWY along with the other destructed MLG components apart;

– the fuse pins («weak links») of the FWD attachment A of both MLG legs are destructed (Fig. 18 and Fig. 19), with the fuse pins bodies remaining into the bearings housings, and the fuse pins heads remaining into the bearings mounting brackets.

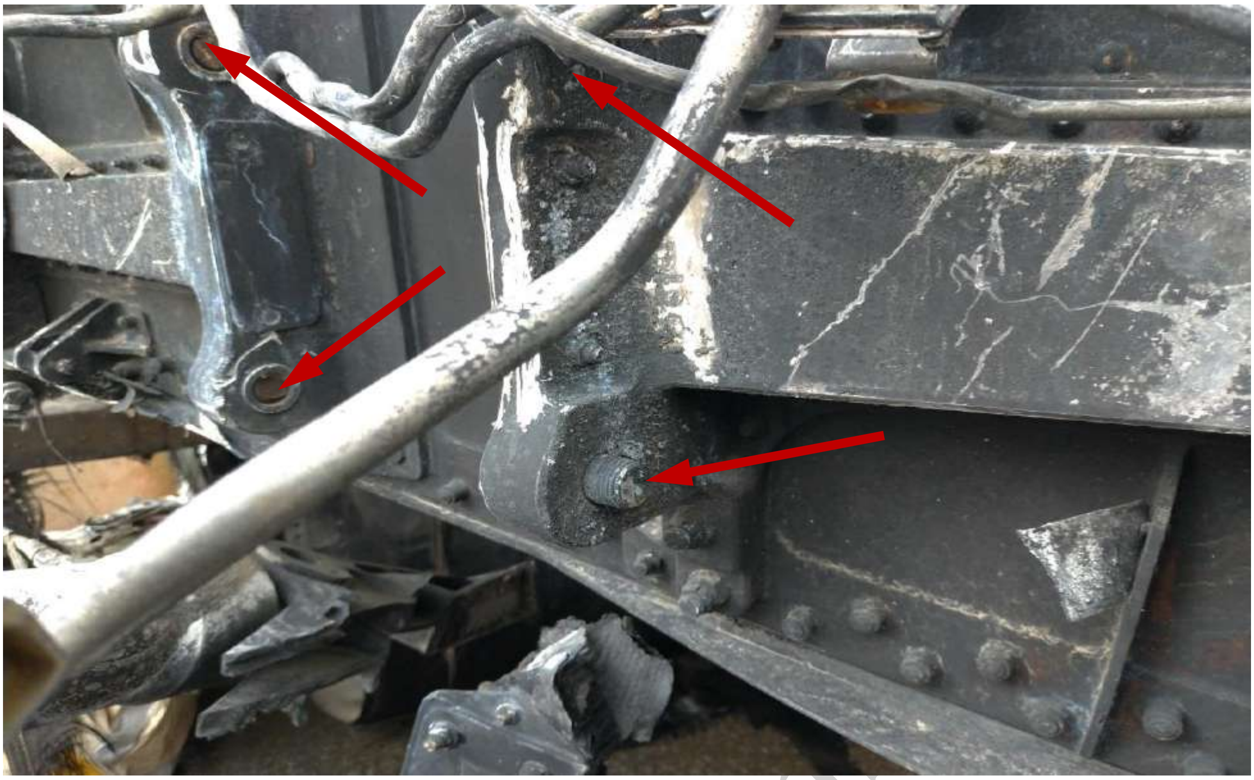


Fig. 18. The left MLG attachment A fitting on the rear spar adjacent to rib 3, the attachment A fuse pins («weak links») are sheared

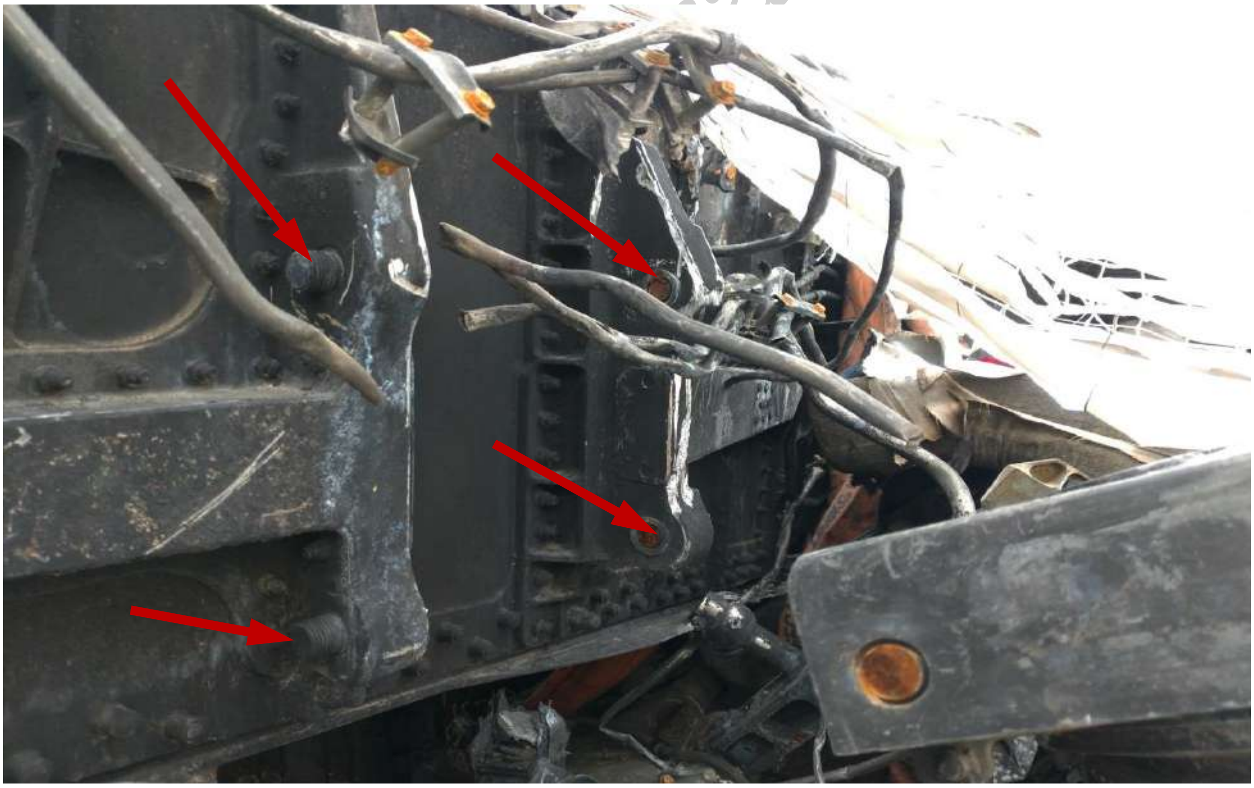


Fig. 19. The right MLG attachment A fitting on the rear spar adjacent to rib 3, the attachment A fuse pins («weak links») are sheared

Wing high-lift devices

– the slats and flaps are observed in an extended position, consistent with the FLAPS 3 configuration (δsl = 24°, δfl = 25°);

– the flight control system elements, located at the F5 compartment on the fin and stabilizer sustained the most significant destruction;

– the transmission shafts, toothed gearing units and the assemblies at the area of the landing gear beam are destructed and disintegrated;

– the wing high-lift devices mechanical damage stems from the airframe structure destruction. Through the areas with no damage to the airframe, it is only the thermal effect on the flaps drive mechanisms.

Propulsion powerplants

At the powerplants inspection it is stated the gas-air ducts of both engines neither are damaged nor have the FOD traces that would result in the engines in-flight cutoff and contribute to the aircraft systems failure or the ground fire. There are no identified signs of the engines uncontained damage (the destruction of the engines cowls, cases, blades in visible segments of the gas-air duct and so forth).

All the thermal damage to the engines is specific to the external fire on ground and allocated adjacent to the exhaust-mixing nozzles. The seats of fire were located above the right and left engines nozzles exit (in the central fuselage).

The hydromechanical latches of the both engines TR pivoting doors are observed in an opened/unlocked position.

APU

The APU is separated off the aircraft structure and damaged.

Avionics (cockpit controls)

At the inspection of the cockpit it has been revealed that the aircraft systems control panels were contaminated with the combustion products, have neither visible mechanical damage nor the traces of liquid exposure.

The following position of the engine start (Fig. 20), fire extinguishing systems (Fig. 21) and batteries (Fig. 22) control panels switches is observed.

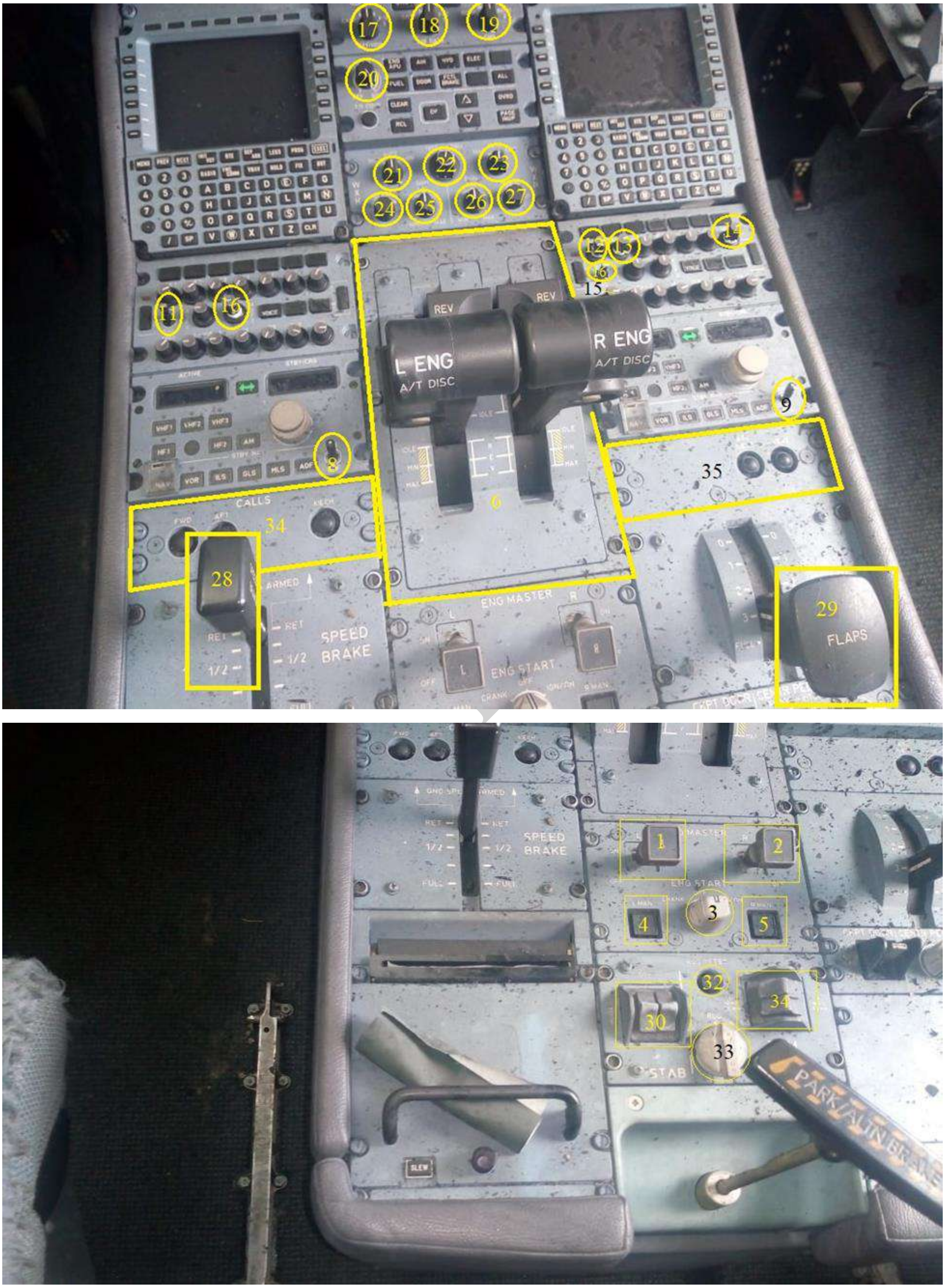


Fig. 20. The post-accident position of the engine control panel switches

Position on Fig. 20	Element	Status	Description
Engine start CP			
1, 2	The ENG MASTER L, ENG MASTER R switches	OFF	The ENG MASTER L and ENG MASTER R switches command the opening and closing of the SOV of fuel feed to the engines. At the ENG MASTER L (ENG MASTER R), switched to the ON position the SOV is open, the fuel is supplied to the left (right) engine. At the ENG MASTER L (ENG MASTER R), switched to the OFF position the SOV is closed, the fuel is not fed to the left (right) engine/shut off. The ENG MASTER L (ENG MASTER R) has the annunciator, on which at the fire detection into the left (right) engine nacelle the FIRE L (R) message is displayed.
3	The ENG START rotary switch	OFF	It is to set the following operational modes of the ignition system: CRANK – the ignition system is switched off, ensures the cranking and false start; OFF – the ignition system is switched off; IGN/ON – the ignition system is active.
TL			
6		IDLE	IDLE – idle thrust

As a result of the performed post-accident inspection of the cockpit it is stated that the APU FIRE (the APU fire protection system (Fig. 21, position # 84)), L ENG FIRE (the left engine fire protection system (Fig. 21, position # 87) and the R ENG FIRE (the right engine fire protection system (Fig. 21, position # 91) switchlights were in an Activated position.

Fig. 21. The post-accident position of the ENG FIRE and APU FIRE switchlights

The switches of all the four batteries are observed in a released (turned off) position (Fig. 22, positions # 52, 53, 54 and 55).

Fig. 22. The post-accident position of the batteries switches

At the fuselage inspection and the evaluation of the condition of the antennas, sensors (ice detector, temperature and AOA sensors), the doors and the cockpit windshield floodlights elements the traces were observed, specific to the lightning exposure (Fig. 23, Fig. 24 and Fig. 25).

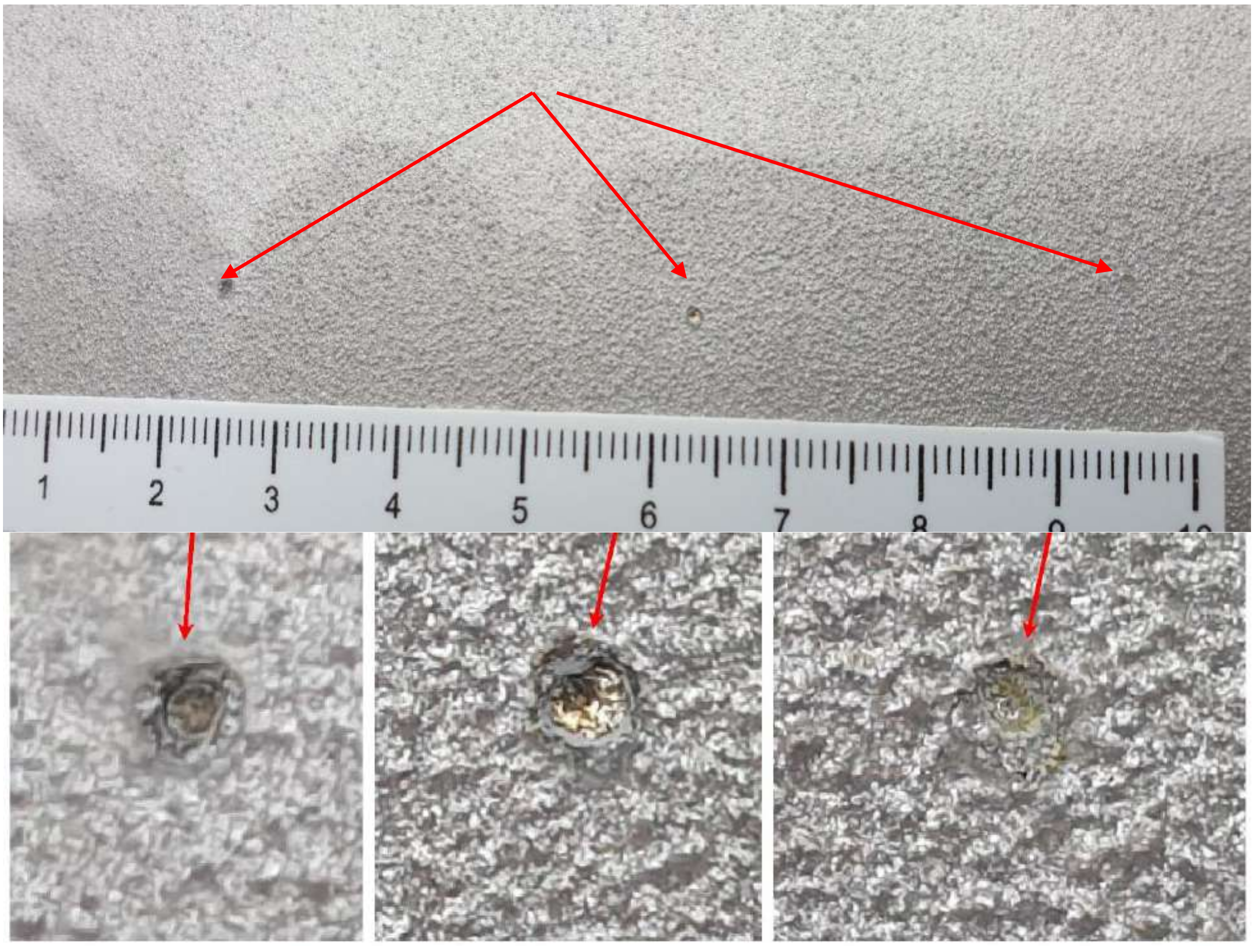


Fig. 23. The lightning exposure traces (pointed with red arrows), adjacent to the TCAS and VHF1 antennas at the upper fore fuselage segment in between FR12-15

Fig. 24. The lightning exposure traces on the right temperature sensor

Fig. 25. The lightning exposure traces on the right ice detector

Besides, the lightning exposure traces are observed on the right aircraft side AOA sensor.

1.4. Other damage

There is no other sustained damage.

1.5. Personnel information

1.5.1. Flight crew

Position	**The RRJ-95B pilot-in-command**
Sex	Male
Age	42
Education	Balashov Higher Air Force Pilots' College, graduation in 1998 in *Command Tactical Aviation*, *Air Transport Operations*, qualified as *an engineer-pilot*
RRJ-95 aircraft transition training	the Aeroflot, PJSC Flight Personnel Training Department (the city of Moscow), the certificate # 092881 of 29.06.2016.
Civil aviation pilot's license	ATPL # 0080723, issued by the Northwestern FATA Interregional Territorial Department on 13.05.2018
Type rating	the RRJ-95 airplane
Medical certificate	on 18.04.2019, I class medical certificate BT # 100782, valid till 18.04.2020, issued by the Aeroflot, PJSC medical center MFEC

Weather minimum	ICAO CAT III 15 x 175 m
Total flying time, of which at: the Yak-52 aircraft, the L-410 aircraft, the Il-76 aircraft / as a PIC the Boeing 737 aircraft / as a PIC	6801 hrs 30 min 42 hrs 16 min 78 hrs 50 min 2201 hrs 19 min / 1488 hrs 35 min 2908 hrs 46 min / 2021 hrs 49 min
the RRJ-95B aircraft flying time / of which as a PIC	1570 hrs 19 min / 1462 hrs 19 min
Flying time within last 30 days	42 hrs 15 min
Flying time within last 3 days	09 hrs 25 min
Flying time on the day of the accident[11]	00 hr 46 min
Total duty time at the day of the accident	02 hrs 12 min
The intervals in flights over the last year	Leave: from 21.05.2018 till 03.06.2018, from 26.07.2018 till 08.08.2018, from 15.10.2018 till 21.10.2018, from 15.01.2019 till 31.01.2019
The date of the last proficiency check	On 31.10.2018, by the flight instructor/examiner, the Aeroflot, PJSC SSJ-100 Air Division Air Squadron # 1 commander, the excellent mark
Land emergency and rescue training	On 08.04.2019 at the Aeroflot, PJSC Flight Personnel Training Department
Water emergency and rescue training	On 12.04.2018 at the Aeroflot, PJSC Flight Personnel Training Department
Simulator training	On 22.02.2019 at the Aeroflot, PJSC Flight Personnel Training Department
Professional advanced training	On 23.08.2018 – the disciplines of the second half-year of 2018

[11] As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, at the airline the flying time of the aircraft crewmembers is logged from the point of the engines startup. The time from the takeoff initiation till the air accident had amounted to 28 min approximately.

	On 19.02.2019 – the disciplines of the first half-year of 2019
Spring and summer period authorization	On 05.04.2019
CRM training	Recurrent training on 04.07.2016 and 29.03.2019, the CRM basic course (initial training) completion certificate had not been submitted to the investigation team (see the details here below)
Preliminary training for air operations through specific regions, routes and aerodromes	On 25.11.2016 at the Aeroflot, PJSC Flight Personnel Training Department
Preflight preparation	Self-preparation on 05.05.2019 at Sheremetyevo airport
Crew rest	More than 50 hrs at home
Preflight medical check	At the Aeroflot, PJSC crew preflight medical check unit at 13:20 on 05.05.2019
Air accidents and incidents in the past	None
English language proficiency	ICAO Level 4, valid till 25.05.2021

After graduating from the Balashov Higher Air Force Pilots' College the PIC[12] served in the Russian Federation Federal Security Service at the flight crew positions. The total flying time over the periods of studies and military service had amounted to 2322 hrs 25 min, the aircraft types he had been performing flights at were Yak-52, L-410, and Il-76.

After retiring from the Russian Federation Federal Security Service aviation within a period from 18.10.2011 till 03.11.2011 he underwent the training at the Ulyanovsk Higher Air College for Civil Aviation under the Other Types of Aviation Flight Crewmembers Training to Be Authorized for the Other (New) Civil Aviation Aircraft Types Transition Training and The Helicopter Pilots to Be Authorized for Civil Aviation Aircraft Transition Training 96 hrs program. On the training completion the CPL for civil aviation had been issued with no indicated type rating[13] (the Ulyanovsk Higher Air College for Civil Aviation HQC # 6 work group Minutes of meeting # 77 of 24.11.2011).

[12] In this Section, the PIC designation refers, inter alia, to those periods of time when the PIC held other positions.
[13] The copy of this License had not been submitted to the investigation team.

Between 26.12.2011 and 04.03.2016 he was employed by the Transaero airline on the positions of the Boeing 737 aircraft F/O and PIC in succession with the total flying time of 2908 hrs 46 min, of which 2021 hrs 49 min as a PIC.

Between 06.03 and 20.03.2012 he underwent the Pilots Specialized Training (category 2) 72 hrs course at the Transaero airline, LLC Air Training Center, following the completion the certificate # ЛО1238-12 of 20.03.2012 had been issued. During the training, as per the Certificate, he successfully passed the tests/exams on the Program basic disciplines with a good mark, including the Aeronautical Meteorology and the EFIS disciplines.

Between 21.03 and 12.05.2012 he underwent the 166 hrs Flight Personnel Boeing 737-300/400/500 Transition Training at the Transaero airline, LLC Air Training Center, following the completion the certificate # ЛО2063-12 of 12.05.2012 had been issued. During the training, as per the Certificate, he successfully passed the tests/exams on the Program basic disciplines with a good mark, including the CRM training.

By the Transaero Airline, LLC Boeing 737 Air Division commander Order # 191 of 17.05.2012 he was authorized for commissioning as the Boeing 737-300/400/500 F/O under the Transaero airline, LLC Boeing 737 Aircraft Flight Crew Training Program.

By the Transaero Airline, LLC deputy general manager – the flight department head Order # 454 of 17.05.2012 he had been authorized for the RNAV 1 flights (including the European region P-RNAV flights) and for the RNAV 2 ones, for the RNAV 5 flights (including the European region B-RNAV flights).

By the Transaero airline, LLC deputy general manager – the flight department head Order # 654 of 29.06.2012 he was authorized for flights performance as the Boeing 737-300/400/500 F/O in an unassigned crew under the ICAO CATI minimum (60 x 550, takeoff at 400 m) with the takeoff and landing performance entitlement.

Between 16.07 and 20.07.2012 he underwent the Civil Aviation Aircraft Flight Crew Advanced Training Program for International Air Operations Performance course at the Transaero airline, LLC Air Training Center in the amount of 182 hrs (out of which 40 hrs of theoretical training, 142 hrs of distance learning), once the course was completed, the Certificate # ЛО3143-12 of 20.07.2012 had been issued.

By the Transaero Airline, LLC Boeing 737 Air Division commander Order # 318 of 13.08.2012 he was authorized to perform flights as the Boeing 737-300/400/500 aircraft F/O in an unassigned crew.

ATPL II П # 000644 was issued permanent on 26.03.2013 by the Russian Federation Ministry of Transport FATA Civil Aviation HQC Chairman. As for Section XII. Ratings the following entries had been introduced in succession: *«самолет многодвигательный,* *сухопутный, БОИНГ 737 300/400/500, второй пилот, от 26.12.2011/multiengine land, BOEING 737 300/400/500, first officer, of 26.12.2011»; «самолет многодвигательный, сухопутный, БОИНГ 737 300/400/500, командир ВС - стажер от 21.06.2013/multiengine land, BOEING 737 300/400/500, trainee pilot-in-command of 21.06.2013», «самолет многодвигательный, сухопутный, БОИНГ 737 300/400/500, командир ВС от 20.08.2013/multiengine land, BOEING 737 300/400/500, pilot-in-command of 20.08.2013».* As for Section XIII. Remarks the following entries had been introduced in succession: *«Issued in accordance with ICAO Standards Выдано в соответствии со стандартами ИКАО»; «English language proficiency level 4 ICAO scale. Valid till 21.09.2014 Chairman RHQC»; «English language proficiency level 4 ICAO scale. Valid till 20.07.2015 Chairman RHQC»; «English language proficiency level 4 ICAO scale. Valid till 25.06.2018 Chairman RHQC».*

By the TRANSAERO airline, LLC deputy general manager – the head of the air operations department Order # 369 of April 18, 2013 the first class of the TRANSAERO airline transport pilot was assigned.

Within 20 – 27.05.2013 he underwent the Initial Training of the Pilots Candidates for commissioning as the PIC course in the amount of 48 hrs at the TRANSAERO airline Air Training Center, with the end of the training he was issued the certificate # ЛО2186-13 of May 27, 2013. During the course, as per the Certificate, he passed credits and the exams in the basic disciplines of the Program, including special training on the human factor at the commissioning as a PIC.

By the TRANSAERO airline, LLC deputy general manager – the head of the air operations department Order # 637 of June 21, 2013 he was approved for line training for solo flights as a Boeing 737-300/400/500 aircraft PIC.

By the TRANSAERO airline, LLC general manager Order # 3615 of August 20, 2013 he was appointed to the position of the Boeing 737-300/400/500 aircraft PIC.

By the TRANSAERO airline, LLC deputy general manager – the head of the air operations department Order # 828 of August 20, 2013 he was authorized to perform flights as the Boeing 737-300/400/500 aircraft PIC at ICAO CAT I minimum, takeoff at 400 m, to perform visual and the circle-to-land approaches at the Boeing 737 aircraft, to perform flights on cruise from the right duty station at the Boeing 737 aircraft.

By the TRANSAERO airline, LLC Boeing 737 aircraft Air Division commander Order # 85 of April 25, 2014 he was authorized to perform flights at the Boeing 737-300/400/500 aircraft at ICAO CAT III minimum, takeoff at 150 m.

By the TRANSAERO airline, LLC deputy general manager – the head of the air operations department Order # 693 of October 1, 2014 he was authorized for flights at the RVSM airspace.

By the TRANSAERO airline, LLC Boeing 737 aircraft Air Division commander Order # 203/1 of October 23, 2014 he was authorized to perform RNP approaches.

On April 15, 2015 he underwent the Safety Management System Initial Training course in the amount of 8 hrs at the TRANSAERO airline Air Training Center, following the end of the training he was issued the Certificate # ЛО2070-15 of April 15, 2015.

On March 04, 2016 he was dismissed under the staff reduction procedure of TRANSAERO airline, LLC.

On April 11, 2016 the application for consent was submitted to the Aeroflot, PJSC deputy general manager – the air operations director on the PIC's SSJ-100 aircraft transition training. The application was signed by the Aeroflot, PJSC Air Operations Department Director and agreed with the SSJ-100 aircraft air division commander and the director of the Flight Safety Department.

Under the Employment Contract # 431 of April 25, 2016 from April 27, 2016 he was employed to the position in the Aeroflot, PJSC Air Operations Department flight crew training division. Equally the respective order was issued by the HR Department deputy director - # 5396/л of April 25, 2016 - on the PIC's employment.

As per the submission by the Aeroflot, PJSC deputy general manager – air operations director (hereinafter referred to as the Submission) and the decision by the commission (the Local Qualification Commission; the Commission's Minutes of Meeting # 07 of April 25, 2016) the pilot was recommended for the RRJ-95 aircraft transition training.

Within 27.04.2016 - 29.06.2016[14] the PIC underwent the training on the RRJ-95 Aircraft Flight Crews Transition Training Program (approved by the head of the Russian Federation Ministry of Transport FATA Flight Operations Department on January 26, 2015) (hereinafter referred to as the Program) as the F/O in the Aeroflot, PJSC Flight Personnel Training Department.

According to item 2 of the «Entrance Requirements for Students» of the explanatory note to the Program the PIC was approved for the training under the special course. At that as per the Duration of Training item of the explanatory note the duration of training amounted to 63 teaching hours of the ground training and 88 astronomical hours of the simulator drill.

Note: *The RRJ-95B Aircraft Flight Crew Transition Training Program explanatory note.*

*«**The Entrance Requirements for Students:***

…

[14]On May 5, 2016 the PIC passed the exam as well on the Aviation Security advanced training course (for the flight and cabin crewmembers) (the Certificate # 091866 of May 05, 2016) in the Aeroflot, PJSC Flight Personnel Training Department with the excellent mark.

*2. **As for the Special Course:** the pilots with the experience of air operations aboard the two-crew airplanes with the Glass Cockpit) of the MTOW not less than 10 tons – 500 hrs.*

***The duration of training**, … 63 teaching hours of ground training and 88 astronomical hours of simulator drill as for the Special Course».*

However under the curriculum of the Program (Special Course) 30 hrs (the FTD/FFS briefing/debriefing) are the part of the ground training. Accordingly, the actual duration of the Program Special Course, under which the PIC was trained, amounted to 93 teaching hrs of the ground training and 58 astronomical hrs of the simulator drill.

It should also be pointed that according to the curriculum of the RRJ-95 Aircraft Flight Crew Transition Training Professional Transition Training Program the aerodrome drill in the amount of 00 hr 45 min is provided for a pilot. The RRJ-95 Aircraft Flight Crew Transition Training Professional Special Transition Training Program curriculum does not provide for the aerodrome drill.

According to the Program (Special Course) curriculum into the FFS simulator training session 4 the performance of the F/CTL DIRECT MODE abnormal procedure was provided for.

Note: *The RRJ-95 Aircraft Flight Crew Transition Training Professional Transition Training Program.*

The Program curriculum.

…

2. Simulator training.

…

item 2.2.4 FFS 4.

…

«Climb and cruise flight:

…

- abnormal procedure: F/CTL DIRECT MODE;

- The piloting in the simplified and minimum modes;

- The series of stalls in various configurations;

…

Descent and approach:

- The ILS approach to a subsequent circle-to-land;

- Go-around;

- Visual circling flight;

- Go-around;

- Visual circling flight;

- Crosswind landing».

As per the Training Summary Record, on 11.06.2016 the PIC underwent the FFS 4 training, which was documented in the TRAINING SUMMARY RECORD. Still based on the submitted documents it is impossible to determine the amount of training, actually completed at the FBWCS DIRECT MODE, as well as the flights actual environment (weather conditions, the airplane weight etc.).

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, no detailed description of each abnormal and emergency procedure drill scenario (including the F/CTL DIRECT MODE) into the RRJ-95B Aircraft Transition Training Program is due to no specific requirements of the FAR «The requirements to the educational institutions and the organizations that train specialists of the appropriate level compliant to the lists of the air personnel specialists. The form and the procedure of issuance of the document to confirm the compliance of the educational institutions and organizations that train specialists of the appropriate level compliant to the lists of the air personnel specialists, the FAR requirements» (the Russian Federation Ministry of Transport Order # 289 of September 29, 2015). According to the Program, the next exercise (session) is started only after the previous exercise (session), in the flight instructor's opinion, is worked out to the required level in line with the current session objectives and/or the criteria.*

On the completion of the transition training the Certificate # 092881 of June 29, 2016 was issued.

On July 12, 2016 the PIC was issued the ATPL # 0047008 by the North-Western FATA Interregional Territorial Department with the ratings as follows: самолет (airplane) RRJ95 Co-pilot, remarks: English language proficiency – Level 4. Date of expiry – 25.06.2018.

According to the Aeroflot, PJSC deputy general manager – air operations director Order # 125.11/1-1097/y of July 18, 2016 (in virtue of the SSJ-100 aircraft air division deputy commander report with the external # 150.16/3286 of July 13, 2016), the PIC was authorized for commissioning as the RRJ-95 F/O from 15.07.2016 till 02.08.2016 as per Variant # 2 according to the Aeroflot, PJSC RRJ-95 Aircraft Flight Crew Training Program (the third edition) (hereinafter referred to as RRJ-95 FCTP), approved by the head of the Russian Federation Ministry of Transport FATA Flight Operations Department on November 25, 2015, with the assigned PIC – flight instructor.

Since the approval to the present the RRJ-95 FCTP is being revised. In the period from the initiation and till the completion of the commissioning as the PIC (November 16, 2016) the pilot underwent the training as per the RRJ-95 FCTP, Revision[15] 2 (this became effective from 27.04.2016), Revision 3 (this became effective from 05.08.2016), Revision 4 (this became effective from 03.10.2016) and Revision 5 (this became effective from 14.11.2016). The introduced Revisions did not affect the PIC's amount and the procedure of the training.

The RRJ-95 FCTP integrates three programs, being the regulatory document, in compliance to which the RRJ-95 aircraft flight crews air training and its improvement are carried out:

Program 1 «The pilots' training for the unsupervised operations»;
Program 2 «Special training»;
Program 3 «Recurrent training and the proficiency attestation».

Program 1 determines the amount of the pilots' training to the PIC-instructor-examiner level and consists of the sections as follows: Section 1: «The pilot's training for solo flights as a F/O», Section 2: «The F/O's training for the commissioning as the aircraft PIC», Section 3: «The training for flights performance as the aircraft PIC», Section 4: «The training of the flight instructor», Section 5: «The training of the flight instructor-examiner».

Program 1 determines the scope of training through six options subject to current level of the pilot's proficiency and the previous experience of air operations.

Variant 2 is applicable to the pilots with the experience of air operations on the aircraft with EFIS ≥ 500 hrs, and with the previous – over the last 10 years – minimum air operations experience[16] as follows: the total flying time in a two-member crew ≥ 500 hrs, the total flying time on the airplanes with MTOW < 90 tons but ≥ 5700 kg as a PIC < 2000 hrs, but ≥ 500 hrs. At the time of transition training the PIC had the total flying time as the Boeing 737 aircraft PIC of more than 2000 hrs, that is his proficiency level corresponded to Variant 2.

Note: *Essentially the PIC's proficiency level was even consistent with Variant 1. As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, taking into account the lack of experience of the air operations aboard the airplanes with FBWCS the air division commander made the decision on the pilot's training under Variant 2.*

[15] These are indicated in the RRJ-95 FCTP Revision Status.
[16] The only options are stated that are consistent with the PIC's proficiency level.

The OM Part A Section 5.2.5. (2), Chapter 5

«…The air division commander (his deputy) shall hold the individual interview with the pilot (flight specialist) on the basis of the comprehensive assessment of the proficiency and the previous flight experience and make the decision on the pilot's training under one of the Variants. The Variant shall not be changed towards the reduction of the Program…».

1.0. GENERAL GUIDELINES TO PROGRAM 1, RRJ-95 FCTP (Third edition) Revision 2

«item 6. On the completion of the transition training and the issuance of the respective certificate the pilot is sent to the air division.

The air division commander (his deputy) holds the individual interview with the pilot (the acquaintance with the pilot), based on the proficiency level comprehensive assessment and previous experience of air operations (according to Program 1 General Guidelines table 1) makes the decision on the pilot's training under one of the Variants. The change of the Variant towards the reduction of the Program is only allowed for the pilots with the previous experience of air operations aboard the A319/320/321, A330 aircraft in the amount, indicated in Program 1 General Guidelines table 2. …».

Variant 2 of the training to air operations (up to the aircraft PIC) involves the training in the amount as follows:

Section 1: Task 1 «Ground training» (the amount of not less than 14 hrs), Task 2 «The line drill of the F/O with the flight instructor» (Exercise 1: «The line drill as a pilot-observer» - 2 flights, Exercise 2: «The line drill as a F/O» - 10 - 20 flights (out of which not less than 5 as a PF)), Task 3 «The check flights for the authorization for solo flights as a F/O » not less than 2 flights, out of which not less than 1 takeoff and 1 landing as a PF;

Section 2: Task 2 «The check flights prior to approval for commissioning as the aircraft PIC» (Exercise 1: «The simulator check flight prior to approval for commissioning as the aircraft PIC» - not less than 2 hrs, Exercise 2: «The line check flight prior to approval for commissioning as the aircraft PIC» - not less than 2 flights);

Section 3 «The training for air operations as the aircraft PIC» in its entirety.

According to item 7 of the Program 1 General Guidelines and item 1 of the General Guidelines Section 1 before the start of the training under the established Program Variant the pilot shall undergo:

the simulator proficiency check, determined in accordance with Task 2 «The simulator proficiency check» of Section 1 «The confirmation of the right to operate flights» of Program 3.

By the Air Operations Department general manager decision the check, having been carried out in the certified air training center, may be recognized as the proficiency one.

the aerodrome drill aboard the aircraft, determined in accordance with Exercise 2 «The aerodrome drill aboard the aircraft» of Task 1a «The aerodrome drill» of Program 1 Section 1 in the event of the failure to carry out the aerodrome drill in the progress of the new aircraft type transition training.

By the air division commander decision the aerodrome drill aboard the aircraft may be replaced or enhanced by the simulator drill in the amount of the ZFTT session compliant to Exercise 1 «Aerodrome simulator drill» of Task 1a of the Program 1 Section 1.

Note: ***RRJ-95 FCTP (Third edition) revision 2***

1.0. Program 1 General Guidelines

item 7. Prior to the start of the training under the established Variant the pilot shall undergo:

- the simulator proficiency check, determined in accordance with the Program 3 Section 1 Task 2. By the Air Operations Department general manager decision the check, having been carried out in the certified air training center, including the foreign one, may be recognized as the proficiency check.

- the aerodrome drill aboard the aircraft, determined compliant to the Program 1 Section 1 Exercise 2, in the event of the failure to carry out the aerodrome drill at the new aircraft type transition training.

As per the air division commander decision the aerodrome drill aboard the aircraft may be replaced or enhanced by the simulator training in the amount of ZFTT (zero flight time training) session according to the Program 1 Section 1 Task 1a Exercise 1...

The replacement of the aerodrome drill by the simulator one at the amount of the ZFTT session is only allowed for pilots with the flying time aboard the multi-crew turbojet transport aircraft of MTOW of ≥ 10000 kg or passenger capacity of ≥ 20 pax of not less than:

- 1500 hrs or 250 flights en route at the level C FFS

or

- 500 hrs or 100 flights en route at the level D FFS.

1.1. Section 1. The pilot's training for solo flights as a F/O

General guidelines to Section 1.

1. In case in the progress of the new aircraft type transition training the aerodrome drill was not carried out, then prior to the start of the training under the established Variant of the Program the pilot shall undergo the training under Task 1a.

By the air division commander decision the training under the Task 1a Exercise 2 may be replaced or enhanced by the training under Task 1a Exercise 1.

The replacement of the training under Exercise 2 by the training under Exercise 1 is only allowed for pilots with the flying time aboard the multi-crew turbojet transport aircraft of the MTOW of ≥ 10000 kg or the passenger capacity ≥ 20 pax of not less than:

- 1500 hrs or 250 flights en route at the level C FFS

or

- 500 hrs or 100 flights en route at the level D FFS.

Task 1a. Aerodrome drill.

The training under this task is not mandatory and is carried out in the event of the failure to carry out the aerodrome drill in the progress of the new aircraft type transition training.

The drill is carried out under Exercise 1 and/or under Exercise 2 as decided by the air division commander.

The only Task 1a Exercise 1 training is allowed for the pilots with the flying time of at least the indicated in the General Guidelines item 1 to this Section.

In the pilot's Flight Experience Record there are no results of the aerodrome drill aboard the aircraft both at the transition training and prior to the start of the commissioning. There is no respective decision by the air division commander on the replacement of the flight drill by the simulator drill in the amount of the ZFIT session either. It is only at the transition training on 29.06.2016 the PIC underwent the simulator drill in the amount of the ZFTT session with the conclusion *«qualified for type endorsement»*. Prior to the start of the commissioning the drill in question (the ZFTT one) had not been carried out.

Note: ***RRJ-95 FCTP (Third edition) revision 2***

Section 1. The pilot's training for solo flights as a F/O

...

Task 1a. Aerodrome drill.

…

Exercise 1. The aerodrome simulator training. 2 hours

Objective: to practice the piloting technique prior to the start of the commissioning.

Instructions: the check is carried out by the Type Rating Examiner/TRE, authorized for the flight crew personnel training under the simulator transition training program in the amount of the ZFTT (zero flight time training) session as per the special method, approved by the Air Operations Department general manager.

Exercise 2. The aerodrome drill aboard the aircraft of 4-6 approaches.

Objective: to practice the piloting technique prior to the start of the commissioning aboard the real airplane.

Instructions: The training is carried out by the Type Rating Examiner/TRE, authorized for the flight drills under the transition training program as per the special method, approved by the Air Operations Department general manager.

…

PAPERWORK:

The results of the drill completion and the authorization for the training for solo flights as a F/O or the aircraft PIC are drawn up on a form (Appendix 1.1A to the Program).

The pilot's Flight Experience Record does not contain the Pilot's Aerodrome Drill Prior to the Commissioning form with the results of the drill completion and the authorization for training for solo flights as a F/O (the examiner's remark in the Conclusion section: *«Authorized to undergo the training for solo flights*», provided for by the Program 1 Appendix 1.1A)).

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, as per the guidelines to the Program 1 Section 1 Task 1 the training under this Task is not mandatory and is carried out if the aerodrome drill (the simulator or the aircraft one) had not been carried out in the progress of the new aircraft type transition training.*

It is in line with the provisions of the RRJ-95 FCTP Program 1 Section 1 General Guidelines item 1 (Edition 3, Revision 2) reading: «If into the new aircraft type transition training the aerodrome drill was not carried out, then before the start of training, compliant to the established variant of the program, the pilot shall undergo training under Task 1a. »

The Program 1 Section 1 Task 1a Exercise 1 had not been carried out, as the FFS drill in the amount of the ZFTT session was arranged on June 29, 2016 as the part of the RRJ-95 Aircraft Flight Personnel Transition Training Program.

The PIC started ground training under Program 1 Section 1 Task 1 on July 4, 2016, that is two weeks before the issuance of the Order on his authorization for commissioning as a F/O with the assignment of the flight instructor. The further assigned flight instructor had not been involved in the ground training under Section 1 Task 1. As per the form of the formalized drill assignment[17] «Training for Flights as a F/O» (issued by the SSJ-100 aircraft air division commander on July 4, 2016, compliant to the Program 1 Appendix 1.1-1), the ground training was carried out within July 4 – July 7, 2016 by different instructors, the total time of training amounted to 14 hrs. The conclusion by one of the instructors of July 06, 2016: *«authorized for drill under Section 1 Task 2 Exercise 1».* This conclusion was similarly made prior to the issuance of the Order on the authorization for commissioning and actual completion of the training under Section 1 Task 1. At that the part of the ground training on July 7, 2016 was carried out not by the flight instructor, whose responsibility this is according to FCTP, but by the engineer[18] and after the conclusion by the instructor on the authorization for the next exercise.

Note: ***RRJ-95 FCTP (Third edition) revision 2***

Program 1

1.1. Section 1. The pilot's training for solo flights as a F/O

General Guidelines

…

«item 2. After establishing the variant of the training to undergo under Section 1 the pilot is assigned to the instructor for undergoing the Tasks 1 and 2 of Section 1. Based on the license (certificate) on the new aircraft type training completion the associated rating shall be introduced to the pilot's license by the competent authority».

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the objective of the commissioning is a consolidation of the practical skills and the proficiency enhancement of the flight specialist in the progress of the flight drill at the line training (the Aeroflot, PJSC OM Part A item 5.2.5. (2)).*

The authorization of the flight specialist for the commissioning and the flight instructor assignment is documented by the Air Operations Department Order.

That is to say, the commissioning refers to the line drill with an instructor and the commissioning does not include ground training. Therefore, the order was issued ahead of the flight drill. Since the assignment of the instructor to the pilot

[17] Hereinafter referred to as the Form.

[18] In compliance with item 2.5 of the Job Responsibilities Section 2 of the Aircraft Operation Lead Engineer Job Description (approved by the Aeroflot, PJSC Air Operations Department general manager on October 16, 2009), this specialist is required to participate in the technical training of flight personnel through the group or individual classes (consultations).

was carried out directly at the documenting of the authorization to the commissioning, the previous elements of the flight specialist training (ground training) were carried out by any assigned instructor of the air division, as well as, when required, by the aircraft operation lead engineer, the navigator-instructor.

As per the available documents, on July 4, 2016 the PIC underwent the training under CRM and Human Factor Flight Personnel Training Program as well (approved by the acting head of the Russian Federation Ministry of Transport FATA Flight Operations Department on May 28, 2015) (Section 2 «CRM Recurrent Training»). At the investigation team request the airline at different times (on May 13, 2019, March 5 and April 14, 2020) submitted three statements on this course amount. The first statement read that the amount of training was 8 hrs/1 day, as per the second one it was 6 hrs (8 teaching hours) / 1 day, the third statement indicated 6 teaching hours /1 day.

As per the Report # 150-671 of July 4, 2019 by the Aeroflot, PJSC deputy general manager - air operations general manager the SSJ-100 air division was subject to the internal investigation (compliant to the Aeroflot, PJSC Air Operations Department general manager Instruction # 150-81 of June 24, 2019), in the result of which it was established that the CRM classes were held on July 4, 2016 in full in the amount of 6 teaching hours.

According to the drill assignment the PIC's training time on July 4, 2016 as per the RRJ-95 FCTP amounted to 4 hrs. This time is indicated in the statement # 150-671 of July 4, 2019 by the Aeroflot, PJSC deputy general manager - air operations general manager.

It should be mentioned as well that as per the Aeroflot, PJSC OM Part A Chapter 5 after the PIC's including in the Aeroflot, PJSC staff he should have undergone the CRM basic course under the Human Factor and CRM Flight Personnel Training Program, the CRM basic course (initial training) completion certificate (license) had not been submitted to the investigation team. The application form of the candidate to the position of a pilot (Aeroflot, PJSC OM Part A Appendix 5.9.1.1.) item 10 (a) «CRM Initial Training» does not contain the mark on the CRM initial training completion.

Note: ***Aeroflot, PJSC Part A Chapter 5 Section 5.2 Personnel Requirements***

Section 5.2.3. Qualification requirements for the flight personnel at the application for a job

…

(*10) After including in the staff of the division the flight specialist shall:*

…

(iii) undergo the CRM basic course;

…».

The Human Factor and CRM FCTP

3. General Guidelines

…

3.3 The recurrence of the training arrangement is determined by the focus of a specific CRM course:

- all the flight personnel is to undergo the one-time Human Factor and CRM initial (basic) training course at the employment by the airline.

The course duration – 4 days (24 hours) …

On the results of the job interview with the air operations department CRM instructor the completion of the CRM basic course at the other airline or the air training center may be acknowledged compliant to the Aeroflot, PJSC standard.

…

3.7 After the successful completion of the 4-day basic course the associated Order is issued at the flight personnel training department. The course listener is issued a standard document.

…

Section 1 The Human Factor and CRM flight personnel initial training (the basic course).

This type of training is intended for the flight crewmembers, have not been earlier trained in CRM or employed by Aeroflot, PJSC from the other airlines…»

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the PIC had undergone the civil aviation CRM initial training at the TRANSAERO airline air training center.*

Through the terminology of the FAR-128 and FAR-147 provisions there is no division of the Human Factor and CRM training into the initial and recurrent one. At the time of the employment in Aeroflot, PJSC the PIC was a holder of a valid ATPL. The FAR-147 items 4.1 and 6.1 determine that the person, who was issued a CPL or ATPL has demonstrated the appropriate knowledge in «human performance, including the principles of threat and error management». In other words the initial training under this discipline is arranged at the educational institutions (training centers) until the obtainment of the CPL/ATPL.

Within March 21 – May 12, 2012 the PIC had undergone the Boeing-737-300/400/500 Aircraft Flight Personnel Transition Training course at the TRANSAERO airline air training center in the amount of 166 hrs. On its completion before the start of performing flights at the TRANSAERO airline he was issued the certificate # ЛО2063-12 of May 12, 2012, according to which the tests and exams were successfully passed in the main disciplines of the Program, including crew resource management (CRM). This means that the CRM civil aviation initial training had been completed by the PIC at the TRANSAERO airline air training center, of which the reporting document is a certificate # ЛО2063-12 of May 12, 2012.

The PIC started the line training on July 17, 2016, prior to the issuance of the Order on the authorization for commissioning as a F/O as well.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the documenting of the authorization for commissioning from July 15, 2016 to August 2, 2016 was arranged on July 13, 2016. The record was introduced to the Corporate Automated Document Management System on July 18, 2016, the delay was due to technical issue.*

As per the Training for Flights as a F/O form (Program 1 Appendix 1.1-2.), Exercise 1 «Line Drill as a Pilot-Observer» of Task 2 «Line Drill» of Section 1 was carried out by the PIC on July 17, 2016 in the amount of 2 flights (02 hrs 05 min)[19] with the instructor, who had not been assigned to the PIC. The conclusion by the instructor of July 17, 2016: *«authorized for the drill under Task 2 Exercise 2»*.

According to the form «The line drill with the flight instructor » (the Program 1 Appendix 1.2-1) under Section 1 Task 2 Exercise 2 the PIC had performed 14 flights[20] (of the duration of 24 hrs 54 min) as a F/O, 12 out of which with the assigned instructor and the two flights of July 19, 2016 had been performed together with the CRM division pilot with the rating of the pilot-examiner. The conclusion by the assigned instructor of July 28, 2016: *«the task is completed, authorized for check flights»*.

Two check flights had been performed on July 29, 2016 together with the flight instructor/examiner – the SSJ-100[21] aircraft air division deputy commander, the conclusion by the

[19] This meets the RRJ-95 aircraft FCTP provisions.
[20] From 10 to 20 flights according to the RRJ-95 aircraft FCTP.
[21] SSJ-100 is a registered trademark of the RRJ-95 airplane.

instructor of July 29, 2016: *«may perform flights as an RRJ-95 aircraft F/O in an unassigned crew».*[22]

Note: ***The RRJ-95 Aircraft FCTP (Third edition) revision 2***

0.4. General Guidelines

…

«item 6. The flight training for the unsupervised air operations is carried out by one instructor. The order on the instructor assignment or replacement with the indication of the reason is issued in accordance with the established procedure. The examiners at the discretion of the flight management shall monitor the commissioning by performing the flights as an instructor under the Commissioning Program».

The Aeroflot, PJSC OM Part A Chapter 4 Section 4.5 The crewing to aircraft:

«item 4.5.2.1. The crewing to aircraft with supervisors

As per the objective, indicated in the flight assignment, command and flight, inspector and instructor (the instructors, examiners) personnel representatives may be included in the crew to carry out the qualification checks, flight personnel drills, as well as the en route inspector checks».

According to the agreement on supplement to the employment contract of August 4, 2016 and Aeroflot, PJSC deputy general manager- air operations director Order # 125.11/1-1406/л of August 4, 2016 the PIC had been transferred to the F/O's position to the Aeroflot, PJSC SSJ-100 air division.

As per the SSJ-100 air division commander Order # 290 of August 4, 2016, on the completion of the program of training for the flights performance, compliant to the RRJ-95 aircraft FCTP, the PIC was authorized for the solo flights in an assigned crew as the RRJ-95 aircraft F/O under ICAO CAT I minimum (60x550, takeoff of 200 m at high intensity lighting). By the same Order to proceed with the line air operations the PIC [Name Surname] was assigned to the pilot.

According to the form «Training for the flights performance in an unassigned crew» (issued by the SSJ-100 air division commander in compliance to the Program 1 Appendix 1.3-4. on August 4, 2016) the PIC performed 15 flights with a total flying time of 23 hrs 09 min (in an assigned crew) under Exercise 1 «Flight Drill» of Task 4 «The F/O's training for the flights performance in an unassigned crew» of Section 1. When undergoing training according to Variant 2, this exercise is not provided for by the RRJ-95 aircraft FCTP. The airline submitted information to the

[22] Initially, in the drill assignment form the conclusion was made on the authorization for flights as a F/O in an assigned crew. Later this conclusion was amended. Variant 2 of the Program does not provide for the training for flights performance in an unassigned crew and the F/O's flight drill under Section 2 «The F/O's training for commissioning as the aircraft PIC».

investigation team that this exercise had been arranged to the PIC by the decision of the management to air operations, the reasons for making such a decision were not stated. On the results of these flights performance the SSJ-100 air division commander on August 27, 2016 concluded: *«Exercise 1 completed, authorized for check flights»*.

From August 22 to August 25, 2016 he underwent the training at the Aeroflot, PJSC Flight Personnel Training Department under the Theoretical Course for Training Pilots Candidates for Commissioning as The PIC-Trainees program, approved by the FATA on February 14, 2014 (the 24 hrs program), on the completion of the training the certificate # 093819 of August 25, 2016 was issued.

Two flights (03 hrs 17 min) under Section 1 Task 4 Exercise 2 were performed on August 31, 2016 with the PIC-flight instructor/examiner, the head of the Safety Management Department. The conclusion by the instructor of August 31, 2016: *«may perform flights aboard the RRJ-95 aircraft as a F/O in an unassigned crew».*

By the SSJ-100 air division commander Order # 335 of August 31, 2016, on the completion of the training program for the flights performance according to the RRJ-95 aircraft FCTP, the PIC was authorized to perform flights as a F/O in an unassigned crew.

According to the Form (issued by the SSJ-100 air division commander as per the Program 1 Appendix 1.4-4): the training under Program 1 Section 2 Task 1 had not been carried out (the training Variant 2 does not provide for doing this Task), the training under Program 1 Section 2 Task 1a had been carried out (as per the data by the Aeroflot, PJSC Accord complex of information systems) on September 12, 2016 and September 18, 2016 by two different instructors (the training Variant 2 does not provide for this Task performance, there is no Form with the results of the training, prescribed by the Aeroflot, PJSC OM Part A Appendix 5.9.8.1., in the flight file). The instructor, who conducted the training on September 18, 2016 concluded: *«authorized to be checked under Task 2 Exercise 1».* The training under Exercise 1: «The check flight on the simulator prior to authorization for commissioning as a PIC» of the Program 1 Section 2 Task 2 had been carried out (as per the data by the Accord complex of information systems) on September 21, 2016 in the amount of 2 hrs[23]. The conclusion by the instructor of September 21, 2016: *«authorized to be checked under Task 2 Exercise 2»* (there is no Form with the results of the training, prescribed by the Aeroflot, PJSC OM Part A Appendix 5.9.8.1., in the flight file).

On September 23, 2016 two flights had been performed of the total time of 02 hrs 57 min under Exercise 2 «The line check flight» of the Program 1 Section 2 Task 2 with the flight instructor – the SSJ-100 air division deputy commander. The conclusion had been written down

[23] This meets the RRJ-95 aircraft FCTP provisions.

by the instructor: *«may undergo the training under section 3 (the commissioning as a PIC) »* (the Pilot Proficiency Check Report as per the Aeroflot, PJSC OM Part A Appendix 5.9.7.1 of September 23, 2016, the excellent general mark).

On October 03, 2016, the SSJ-100 aircraft air division commander submitted a report to the deputy general manager – air operations director (agreed with the air operations director and the head of the human resources department) with a recommendation to authorize a pilot for commissioning as a trainee PIC under the training Variant 5 with the assignment of the flight instructor to him for the arrangement of the ground and flight drill with the period of commissioning from October 10, 2016 to December 27, 2016. The specific reasons for the training variant change (from Variant 2 to Variant 5) had not been submitted to the investigation team. The order to change the training variants is not determined in the RRJ-95 Aircraft FCTP. The necessity to undergo additional training as per the previous sections at the variant change to the increased one, that is to the Variant with a larger amount of training is not determined namely. The PIC had not been subject to additional training at the Variant change.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, compliant to the OM Part A item 5.2.5. (2) the air division commander (his deputy) shall hold the individual interview with the pilot (flight specialist) on the basis on the proficiency and previous flight experience comprehensive assessment and make the decision on the pilot's training under one of the Variants. The Variant shall not be changed towards the reduction of the Program.*

By the Aeroflot, PJSC deputy general manager – air operations director Order # 125.11/1-1595/y of October 5, 2016 (on the basis of the SSJ-100 aircraft air division commander Report with the internal number 150.16/4740 of October 3, 2016) he had been authorized for commissioning as a SSJ-100 aircraft air division PIC under Variant 3[24] from October 10 to December 27, 2016 with the assignment of the flight instructor to him.

The RRJ-95 aircraft FCTP (Third edition) revision 4 Variant 5 of the training for flights performance as an aircraft PIC (it became effective from October 3, 2016) provided for the undergoing in full of:

Section 2 «The F/O's training for commissioning as a PIC»: Task 1 «The F/O's flight drill» (the amount of not less than 1000 hrs or not less than 400 flights and 12 months), Task 1a

[24] According to the airline statement the document contained a technical error. Actually the training had been carried out under Variant 5.

«Simulator training» (6 hrs), Task 2 «The simulator (not less than 2 hrs) and line check flight (not less than 2 flights)»;

Section 3 «The training for flights as an aircraft PIC»: Task 1 «Ground training» (the amount of 05 hrs 30 min at least); Task 2 «Simulator training» (the amount of 12 hrs at least); Task 3 «The line drill with the flight instructor» (30-46 flights); Task 4 «The check flights prior to authorization for solo flights as a PIC» (2 flights at least); Task 5 «The solo flights under the authority of the flight instructor» (6-10 flights); Task 6 «The training for the flights performance in an unassigned crew» (100-200 hrs).

As for the training under Section 2 the PIC had only undergone it under Task 1a[25] and 2 (this training had been conducted before the issuance of the order on the training variant change). The PIC had not undergone Section 2 Task 1 training.

The pilot started the Section 3 Task 1 training on October 3, 2016, that is to say before the issuance of order on his authorization for commissioning as a PIC.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the pilot started the training for flights performance as a PIC on October 3, 2016 from the date the SSJ-100 aircraft air division commander issued a report with the recommendation for training under Variant 5. According to the OM Part A item 5.2.5. (2) the objective of the commissioning is a consolidation of the practical skills and the proficiency enhancement of the flight specialist in the progress of the flight drill at the line training. Thus, the commissioning is a practical stage of the training, by the start of which the pilot is issued the due order to authorize him commissioning as an aircraft PIC with the flight instructor, assigned to him.*

As per the form «The aircraft PIC training» (it was issued by the SSJ-100 aircraft air division commander on October 3, 2016, compliant to the Program 1 Appendix 1.5-1.), Task 1 «Ground training» of Section 3 had been undergone on October 3, 2016 (at the amount of 5 hrs 30 min) under the authority of the instructor. The conclusion by the instructor of October 3, 2016: *«authorized for training under Task 2».*

Note: ***The RRJ-95 aircraft FCTP (Third edition) revision 4***

1.3. Section 3. The training for flights performance as an aircraft PIC

General Guidelines to Section 3

…

[25] The training under Task 1a for Variant 2 is not provided for.

«item 3.The instructor is assigned to the candidate to be commissioned by the Air Operations Department director Order (the F/O is to be included in the crew by the beginning of the training under Task 5) …».

At the same day, on October 3, 2016, «The training and authorization of the aircraft PIC to perform takeoffs at the RVR less than 400 m», provided for by Program 2 Section 1 Task 2 was carried out (the Training and Authorization of the Aircraft PIC to Perform Takeoffs at the RVR Less than 400 m form was issued by the SSJ-100 air division commander on October 03, 2016 as per the Program 2 Annex 2.2-1.) in the amount of 02 hrs.

The training under Program 1 Section 3 Task 2 «Simulator training» was carried out within October 12 – October 14, 2016 in the amount of 12 hrs[26] (as stated in the Aircraft PIC's Training form that was issued by the SSJ-100 air division commander on October 04, 2016 as per the Program 1 Annex 1.5.):

the Exercise 1 «The performance of flights and standard procedures» was carried out on October 12, 2016 in the amount of 03 hrs with the instructor, who had conducted the ground training, with the excellent mark, the instructor's conclusion: «*Authorized for the drill under Task 2 Exercise 2»;*

the Exercise 2 «The performance of flights in abnormal and emergency situations» was carried out within October 13 – October 14, 2016 in the amount of 06 hrs with the assigned instructor, the good mark, the instructor's conclusion: «*Authorized for check under Task 2 Exercise 4»;*

the Exercise 3 «The LOFT scenario drill» was completed on October 12, 2016 in the amount of 01 hr with the instructor, who conducted the ground training, with no assessment, the instructor's conclusion: «*The exercise has been completed»;*

the Exercise 4 «The simulator qualification check» was carried out on October 14, 2016 in the amount of 02 hrs with the assigned instructor, the instructor's conclusion: «*Authorized for drill under Task 3».*

The training under Task 2 was combined with the scheduled simulator drill and check as per «The Aeroflot, JSC Pilots' FFS scheduled drill and check program» (approved by the Ministry of Transport FATA Flight Operations Department head on June 18, 2014) (hereinafter referred to as the Simulator Drill and Check Program). As per the Pilots' Simulator Drill and Check form (Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) of October 14, 2016, the instructor's conclusion: «*He meets the civil aviation line pilot qualification. He may perform flights as an aircraft PIC»*, the excellent mark.

[26]This meets the RRJ-95 aircraft FCTP provisions.

As per the explanatory note to the Simulator Drill and Check Program the simulator training is arranged in a three-year cycle, including two training/check sessions a year of the 6/2 hrs duration each.

For every half-year, compliant to the Method Guidance on the Application of the Simulator Drill and Check Program, the deputy general manager – air operations director or the air operations department director shall develop and approve the RRJ-95 FFS Pilots' Drill and Check Manual, which incorporates organizational instructions, the drill/check scenarios, the method of their performance, the charts, the maps in use at the drill/check, the samples of the documentation filling out (compliant to Aeroflot, PJSC OM Part A Appendices 5.9.8.1. and 5.9.11.) and the associated reference material.

The pilot's scheduled simulator drills Record Sheet list (Appendix 5.9.11.) includes the drill elements by three categories: these, subject to drill at least once in 7 consecutive months (at each drill); these, subject to drill at least once in consecutive 12 months; these, subject to drill at least once in consecutive 36 months. The list in question does not incorporate the performance of the F/CTL DIRECT MODE abnormal procedure.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, this procedure is practiced based on one of the drill/check scenarios, provided for by the RRJ-95 FFS Pilots' Drill and Check Manual for the respective half-year. The regulatory documents do not integrate the requirements on the provision of the material (evidence base) on the associated failures at the drill of certain elements or procedures. For instance, as for the exercise to drill the actions at the engine failure the Pilots' Drill and Check Manual does not integrate the associated TR, hydraulic system etc. failures. As recommended by the manufacturer to drill the Unreliable Air Speed Indication element the consecutive blockage of all the pitots is introduced.*

From October 12 to October 14, 2016 the SSJ-100 FFS drill and check was arranged to the PIC at the Aeroflot, PJSC Air Personnel Training Department under the authority of two instructors (the first conducted the drill on October 12-13, 2016 and the second (the assigned one) conducted the check on October 14, 2016), compliant to the RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on June 1, 2016 for the instructors over the period of July – December 2016). The performance of the F/CTL DIRECT MODE abnormal procedure is envisaged by the exercise 6.2.13 «UNRELIABLE AIR SPEED INDICATION» into the drill of October 14, 2016. The Manual does not provide for the performance of go-around in DIRECT MODE. The Pilots' Simulator Drill and Check form item 7 «System Failures» (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) reads that the check was conducted to the PIC of the F/CTL DIRECT MODE abnormal procedure, the excellent mark.

Note: ***FAR-128 item 5.84***

An operator shall prevent aircraft flight crewmembers from performing their duties unless they are trained under the training program, designed by the operator, that ensures the flight crewmembers are appropriately trained to perform their assigned duties and:

…

e) provides for the following:

…

the FFS simulator training arrangement at least once every 36 consecutive months on the failures of all the systems, not attributable to the emergency, including the check.

The RRJ-95 FFS Pilots' Drill and Check Manual *(approved by the Aeroflot, PJSC deputy general manager – air operations director on June 1, 2016 (for the instructors over the July-December 2016 period)).*

The UNRELIABLE AIR SPEED INDICATION exercise is MANDATORY for this half-year period.

6.2.13 UNRELIABLE AIR SPEED INDICATION (CM1)

The beginning of the exercise: TO position RW 22R

The simulator settings to arrange the exercises:

IOS-MALF's NAVIGATION SYSTEM (34) – 3 PITOT BLOCK[27]

The reminders (instructions) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing».

As for the drill assignment it is impossible to figure out in what actual amount and at what parameters (the airplane weight, approach speed, etc.) the DIRECT MODE drill had been carried out. The investigation team request to provide the associated statement by the instructor, who conducted the training, had not been responded.

The line drill under Task 3 was carried out over October 16 – November 9, 2016 with the performance of 32 flights[28] of a flying time of 54 hrs 35 min (as per the Line Drill with the Flight

[27] The blockage of three pitots results in the FBWCS reversion to DIRECT MODE.
[28] The RRJ-95 aircraft FCTP provides for the performance of 30 to 46 flights.

Instructor form that was issued by the SSJ-100 air division commander on October 14, 2016, compliant to the Program 1 Appendices 1.2-1 and 1.2-2.). Apart of the assigned instructor the pilots-examiners were engaged in the drill: the SSJ-100 air division senior flight instructor, the CRM section flight instructor, the flight standards department senior flight instructor, the SSJ-100 air division air squadron # 3 flight instructor. 16 flights out of 32 (50%) had been performed with the assigned instructor. The conclusion by the SSJ-100 air division air squadron # 3 flight instructor of November 9, 2016: *«the task has been completed, the pilot is authorized for check flights».*

Two check flights with the total flying time of 03 hrs 36 min under Task 4 «The check flights prior to authorization for solo flights as an aircraft PIC» of the Program 1 Section 3 had been carried out on November 13, 2016, the SSJ-100 air division commander had been a supervisor (the Pilot's Qualification Check Report, compliant to the Aeroflot, PJSC OM Part A Appendix 5.9.7.1. of November 13, 2016, the general excellent mark). The supervisor wrote down the conclusion: *«The pilot meets the civil aviation line pilot qualification with the entitlement to perform solo flights as an aircraft PIC»*.

On November 16, 2016 on the recommendation by the Aeroflot, PJSC Air Operations department director the FATA North-Western Interregional Territorial Department issued the ATPL # 0044870, the type ratings: самолет RRJ-95/the RRJ-95 airplane, remarks: English language proficiency – Level 4. Valid till June 25, 2018.

By the SSJ-100 air division commander order # 468 of November 17, 2016, from November 17, 2016 he had been authorized for the SSJ-100 flights performance as a PIC in an assigned crew, having been entitled to perform: the visual and circle-to-land approach; the ILS approach and the landings in weather conditions under at least ICAO CAT I (60x550, takeoff of 200 m at high intensity lighting) with no additional restrictions. At that to perform the line flights the SSJ-100 air division F/O[29] was assigned to the PIC.

According to the agreement on supplement to the employment contract of November 17, 2016 and Aeroflot, PJSC deputy general manager- air operations director Order # 125.11/1-1637/л of November 17, 2016, he was transferred to the position of the Aeroflot, PJSC SSJ-100 aircraft air division PIC.

[29] The FCTP and OM did not integrate specific requirements to the F/O's proficiency to be assigned to the newly commissioned PIC. At present, according to item 4.5.1. «The flight crewing to aircraft» of the Aeroflot, PJSC OM Part A Chapter 4 Section 4.5, at the crewing it is taken into account that one of the pilots in the minimum crew should have sufficient flight experience aboard this aircraft type on the completion of the transition training and commissioning (the authorization for solo flights) (this aircraft type flying time of at least 200 hrs, and in case the F/O had undergone the training under the commissioning program Variant V or VI, he shall perform at least 100 flights additionally aboard this aircraft type).

As per the Aeroflot, PJSC deputy general manager – air operations director Order # 125.11/1-1862/y of November 21, 2016 the date of November 16, 2016 is considered the date of the completion of the commissioning as the SSJ-100 PIC.

6 line flights[30] were performed between November 20 – November 24, 2016 with the flying time of 11 hrs 55 min (as per the Line Training with the Flight Instructor form that was issued by the SSJ-100 air division commander on November 15, 2016, compliant to the Program 1 Appendices 1.2-1 and 1.2-2.) under Task 5 «The solo flights under the authority of the flight instructor» of the Program 1 Section 3. The personnel as follows was engaged to the flights as the instructors: the SSJ-100 air division air squadron # 3 commander and the senior flight instructor, the aviation safety management department deputy head, who made the conclusion of November 24, 2016: *«Authorized for solo flights».*

Over November 26, 2016 – February 25, 2017 the pilot's training was carried out for the flights performance in an unassigned crew (56 flights with a flying time of 118 hrs 26 min)[31] under Program 1 Task 6 Exercise 1 «Self-drill» (as per the Training for the Flights Performance in an Unassigned Crew form, issued by the SSJ-100 aircraft air division commander on November 25, 2016, compliant to the Program 1 Appendices 1.3, 1.3-1 and 1.3-4). As far as January 31, 2017 the flights were performed with the earlier assigned F/O. As per the SSJ-100 aircraft air division commander Order # 46 of January 31, 2017 due to the operational necessity there had been a change of the assigned F/O.

Note: ***The RRJ-95 aircraft FCTP, Program 1 Section 3***

Task 6. The training for flights in an unassigned crew.

Task 1. The self-drill

…

Instructions: The solo flights shall be performed in an assigned crew …

Two line check flights under Exercise 2 «Check flights» of the Program 1 Task 6 were performed on February 28, 2017, the SSJ-100 aircraft air division flight instructor was a supervisor. The conclusion by the supervisor of February 28, 2017: *«May perform flights aboard the RRJ-95 airplane as a PIC in an unassigned crew»*. By the SSJ-100 aircraft air division commander Order # 120 of February 28, 2017 he was authorized to perform flights in an unassigned crew.

By the SSJ-100 air division commander Order # 94 of February 15, 2017 he was authorized for the flights under ICAO CAT III A minimum (15 x175, takeoff of 150 m at high intensity lighting).

[30] The RRJ-95 Aircraft FCTP provides for the performance of 6 to 10 flights.
[31] The RRJ-95 Aircraft FCTP provides for the performance of flights with the duration from 100 to 200 hrs.

On March 15, 2017 the PIC was arranged the drill at the SSJ-100 FFS at the Aeroflot, PJSC flight crew training department under the RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on November 28, 2016 (for the instructors, over the period of first half-year of 2017)) under the authority of the simulator instructor, on March 17, 2017 the PIC was arranged the drill and check at the SSJ-100 FFS under the authority of the SSJ-100 air division flight instructor.

The performance of the F/CTL DIRECT MODE abnormal procedure is provided for by the UNRELIABLE AIR SPEED INDICATION exercise 1.1.25 scenario, practiced at the drill on March 15, 2017. The performance of go-around in DIRECT MODE is not implied. As for the drill assignment and the record sheet of the scheduled drills of the pilot at the simulator it is impossible to make the conclusion on the actual doing of the 1.1.25 UNRELIABLE AIR SPEED INDICATION exercise 1.1.25. The System Failures item 7 of the Pilots' Simulator Drill and Check form (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) does not read the entry on the performance of the drill in DIRECT MODE.

Note: ***The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on November 28, 2016 (for the instructors, over the period of the first half-year 2017))***

1.1.25 UNRELIABLE AIR SPEED INDICATION (CM1)

The beginning of the exercise : TO position RW 27

The simulator settings to carry out the exercise:

IOS-MALF's NAVIGATION SYSTEM (34) – 3 PITOT BLOCK

The reminder (instructions) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing».

As per the staff report by the simulator instructor of October 31, 2019, the PIC's drill at the SSJ-100 FFS was held on March 15, 2017 under the RRJ-95 FFS Pilots' Drill and Check Manual for this half-year. The investigation team request to provide more detailed data on the exercises (modes), actually practiced at the FBWCS operation in DIRECT MODE had not been responded. The flight instructor's staff report had not been submitted either due to the resignation from the airline.

By the Aeroflot, PJSC acting deputy general manager – air operations director Order # 125.11/1-345/л of June 9, 2017 he was transferred to the position of the Aeroflot, PJSC SSJ-100 aircraft air division air squadron # 1 PIC.

Over September 13 – 14, 2017 under the authority of the instructor of the simulator and the CRM section flight instructor (the person in charge of the check) the PIC was held the SSJ-100 FFS drill and check at the Aeroflot, PJSC flight crew training department, including under the UPSET RECOVERY exercise 2.2.7 scenario (the airplane recovery from the unusual (abnormal) attitude) under the RRJ-95 FFS Pilots' Drill and Check Manual over the second half-year of 2017). The scenario of this exercise provides for the airplane upset recovery in DIRECT MODE. As part of this drill[32] the approach, go-around and landing in DIRECT MODE are not implied. In the pilot's record sheet of the scheduled drills at the simulator this drill is stated completed.

Note: ***The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on May 31, 2017 (for the instructors, over the period of the second half-year of 2017))***

2.2.7 UPSET RECOVERY (CM 1)

The settings to practice the exercise: ... In a level flight ... (to put the airplane in DIRECT MODE by turning the ADS on/off).

Reminder (instructions) to the instructor:

- To engage DIRECT MODE;

- Ask the CM 1 to close the eyes;

- At this point the CM 2 shall enter the airplane in the upset (in roll and pitch);

- Then the CM 1 – you have control.

Over March 3 – 4, 2018 under the authority of the instructor of the simulator and the SSJ-100 air division flight instructor (it was he, who conducted the check) the drill and check at the SSJ-100 FFS at the Aeroflot, PJSC Flight Personnel Training Department was carried out with the PIC, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual (over the period of the first half-year of 2018). As per the Manual, on the second day of the drill (on March 4, 2018) the LOFT drill had been envisaged[33].

As part of this drill the performance of the flight in DIRECT MODE is provided for without referring to specific legs. The record sheet of the scheduled drills of the pilot at the simulator the LOFT scenario undergoing had been noted. The System Failures item 7 of the Pilots' Simulator Drill and Check form (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) does not have the entry on the DIRECT MODE drill completion.

[32] According to the RRJ-95 FFS Pilots Drill and Check Manual, the doing of this exercise is scheduled for the second day of the drill on September 14, 2017.
[33] The list of this drill provides for the UNRELIABLE AIR SPEED INDICATION exercise.

Note: ***The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on November 29, 2017 (for the instructors, over the period of the January – June of 2018))***

2.3 LOFT (THE SECOND DAY)

The list of exercises

The reminder to the instructor!

In the progress of the drill the instructor is required to carry out (practice): …

Unreliable airspeed indication[34].

The FFS settings to practice the exercise:

IOS-MALF's NAVIGATION SYSTEM (34) – 3 PITOT BLOCK

The reminder (guidance) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing.

As per the staff report by the SSJ-100 air division flight instructor the PIC's drill at the SSJ-100 FFS was carried out, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual for this half-year. The request by the investigation team to submit more detailed data on the actually performed exercises (modes) at the FBWCS operation in DIRECT MODE had not been responded.

On June 13, 2018 on the recommendation by the Aeroflot, PJSC Air Operations department director the FATA North-Western Interregional Territorial Department issued the ATPL # 0080723, the type ratings: самолет RRJ-95/the RRJ-95 airplane, remarks English language proficiency – Level 4. Valid till May 25, 2021.

On August 29, 2018 under the authority of the instructor of the simulator the drill at the SSJ-100 FFS at the Aeroflot, PJSC Flight Personnel Training Department had been conducted to the PIC, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual (over the period of the second half-year of 2018). On August 30, 2018 under the authority of the senior flight instructor, the deputy head of the Safety Management Department the drill and check at the SSJ-100 FFS had been carried out.

The performance of the F/CTL DIRECT MODE abnormal procedure is provided for by the 4.1.23 «STALL RECOVERY» exercise scenario and the scenario of the 4.1.24 «Unreliable Air Speed Indication» exercise (as per the Manual, the exercises had been carried out on the first day of the drill on August 29, 2018). These exercise scenarios do not imply the performance of go-around in DIRECT MODE. The record sheet of the scheduled drills of the pilot at the simulator

[34] The unreliable airspeed indication results in the FBWCS reversion to DIRECT MODE.

notes the completion of the drill under the scenario of the airplane recovery out of the pre-stall and stall modes. As for the drill assignment and the record sheet of the scheduled drills of the pilot at the simulator it is impossible to figure out the actual completion of the 4.1.24 «Unreliable Air Speed Indication» exercise. The System Failures item 7 of the Pilots' Simulator Drill and Check form (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) does not have the entry on the DIRECT MODE drill completion.

Note: ***The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on May, 22, 2018 (for the instructors, over the period of July-December of 2018))***

4.1.23 STALL RECOVERY (PF-CM 1)

The settings (of the simulator) to practice the exercise: … DIRECT MODE ….

The reminder (guidance) to the instructor: …

- To activate the DIRECT MODE. Maintain altitude and idle up to the trigger of the STALL, STALL, STALL warning. To demonstrate maximum AOA and pitch attitudes (the actions on the recovery afterwards).

4.1.24 Unreliable airspeed indications

The settings to practice the exercise: IOS-MALF'S NAVIGATION SYSTEM (34) – 3 PITOT BLOCK

The reminder (guidance) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing.

According to the staff report by the instructor of the simulator the PIC's drill at the SSJ-100 FFS had been carried out on August 29, 2018, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual for this half-year. The request by the investigation team to submit more detailed data on the actually practiced exercises (modes) at the FBWCS operation in DIRECT MODE had not been responded. According to the staff report by the Safety Management Department head the program of the second day of the drill had not envisaged the exercises with the simulation of the flight in the FBWCS DIRECT MODE and the overweight landings, there had been no basis to establish these conditions at the simulator.

Over February 21 – 22, 2019 under the authority of the instructor of the simulator and the SSJ-100 aircraft air division air squadron # 1 (it was he, who conducted the check) the drill and check at the SSJ-100 FFS at the Aeroflot, PJSC Flight Personnel Training Department had been conducted to the PIC, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual (over the period of the first half-year of 2019). As per the Manual on the second day of the drill (on February 22, 2019) the LOFT drill had been envisaged. The list of the exercises into this drill integrates exercise 5.1.L «Unreliable Air Speed Indication».

This drill does not imply the performance of go-around in DIRECT MODE. The record sheet of the pilot's scheduled drills at the simulator reads the completion of this drill. The System Failures item 7 of the Pilots' Simulator Drill and Check form (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) does not have the entry on the DIRECT MODE drill completion.

Note: ***The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on November 26, 2018 (for the instructors, over the period of January-July of 2019))***

2.2 LOFT (THE SECOND DAY)

The list of exercises

Reminder to the instructor!

…

In the progress of the drill the instructor is required to carry out (practice):

…

5.1. L Unreliable Air Speed Indication. …

The settings to practice the exercises: IOS-MALF'S NAVIGATION SYSTEM (34) – 3 PITOT BLOCK

The reminder (guidance) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing.

According to the staff report by the SSJ-100 aircraft air division air squadron # 1 commander the PIC's drill at the SSJ-100 FFS had been carried out on August 29, 2018, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual for this half-year. The request by the investigation team to submit more detailed data on the actually practiced exercises (modes) at the FBWCS operation in DIRECT MODE had not been responded.

On April 8, 2019 the PIC underwent the drill under the Aeroflot, PJSC A 320/321/330, B 737/777, RRJ-95 Aircraft Flight Crews' Emergency and Rescue Training Program, approved on June 19, 2018 by the FATA Aerospace Search and Rescue Arrangement department head as per module 3 «The annual training» in the amount of 16 teaching hrs (the drill assignment of April 8, 2019).

By the SSJ-100 aircraft air division commander order # 124 of April 5, 2019 as having completed full training under the seasonal training program at the Aeroflot PJSC Flight Personnel

Training Department, he was authorized to perform flights in the spring-summer period of 2019 under the earlier established weather minimum.

As per the recommendation by the Aeroflot, PJSC deputy general manager – air operations director and the decision by the Commission (local qualification commission) (the Commission Minutes of Meeting # 5/1 of March 11, 2019), from March 20, 2019 the PIC had been recommended for the initial training as the SSJ-100 aircraft instructor.

According to the Order # 125.11/1-530/y of March 14, 2019 the PIC had been sent for the off-the-job/full-time training at the Aeroflot, PJSC Flight Personnel Training Department for the period of time over March 20 – April 5, 2019 under the Flight Instructor Training additional professional advanced training program.

As per the form «The PIC's training to perform flights from the right seat » (issued by the SSJ-100 air division commander on April 10, 2019, compliant to the Program 1 Appendix 1.6-1, though with no signature, just the surname is indicated), over April 9-10, 2019 the PIC underwent the training under Task 7 «The PIC's training to perform flights from the right pilot's seat» of the Program 1 Section 3.

By the SSJ-100 aircraft air division commander Order # 138 of April 10, 2019, upon the completion of the training, compliant to the RRJ-95 FCTP the PIC had been authorized to perform flights from the right pilot's seat.

The drill and the piloting technique check at the ILS raw data approach for landing had been conducted on a regular basis to the PIC, annually, at least once in 12 consecutive months, according to the RRJ-95 FFS Pilots' Drill and Check Manual, designed and approved for every half-year, compliant to the Aeroflot, PJSC Pilots' Scheduled Drill and Check at the FFS Program (approved by the Russian Federation Ministry of Transport FATA Flight Operations Department head on June 18, 2014).

At the carry out of the drill and check of this element the simulation of the required situation at the simulator (the approach pattern, weather conditions, the automation level etc.) had been arranged, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual of the respective half-year.

The results of the check of the piloting technique by the ILS raw data are given in column 3.1. of the Simulator Check table of the Pilots' Simulator Drill and Check form. It filled in excellent in the forms of 2016 second half-year, the first half-years of 2017, 2018, 2019.

The content of the simulator sessions for the entire time of employment by Aeroflot, PJSC (at the RRJ-95 type transition training, the commissioning, the recurrent training) had not provided for the drill and check on the crew's actions as per the OVERWEIGHT LANDING procedure, set out in the RRJ-95 QRH.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, according to the RRJ-95 aircraft Flight Crew Transition Training Program, the Aeroflot, PJSC flight crew personnel drill on the actions at the overweight landing is carried out at the FFS 10 simulator session under «general» training program and at the FFS 6 simulator session under «special» training program.*

Thus the PIC's drill under this exercise was carried out on June 15, 2016 in the progress of the RRJ-95 aircraft transition training. At that the TRAINING RECORDS RRJ-95 (Special Program), 3К-151.11-023 document reads the instructor's conclusion on the satisfactory result of the drill through all its elements.

According to the «Method for conducting the pilot's simulator training for the flights performance as the RRJ-95 aircraft PIC» (approved by the Aeroflot, PJSC deputy general manager – air operations director on September 7, 2015):

At the doing of the exercises 2.2.1-2.2.4 of the first day of the drill the value of the TOW is 43 tons. As per the established scenario of these exercises these are to simulate: «the engine failure with fire, which cannot be extinguished», after that the crew shall make the decision on the immediate return and landing at the departure aerodrome at the weight, exceeding the maximum allowed landing weight. The drill on these exercises was arranged to the PIC on October 12, 2016.

On March 17, 2017 in the progress of the drill at the FFS under the scenario of the second day at the doing of the LOFT exercise, depending on the established scenario, selected by the instructor, the intended weight had been of 42390 kg (URSS-URMM), or 42180 kg (URSS-URKK), or 43460 kg (URSS-URFF). In case of the PIC's decision to return to the departure aerodrome the situation may be simulated of the overweight landing, which is consistent with the Table of elements item 5.1.1 of the RRJ-95 Simulator Crew Line Operational Simulation (LOS) Manual in addition to the mandatory elements, stated in Chapter 2.2 of the RRJ-95 FFS Pilots' Drill and Check Manual (first half-year of 2017).

On March 04, 2018 in the progress of the drill at the FFS under the scenario of the second day at the beginning of the exercise 3.2.5 EMERGENCY DESCENT (LANDING) (CM1) of the RRJ-95 FFS Pilots' Drill and Check Manual (first *half-year of 2017) the aircraft weight was 44000 kg, which significantly exceeds the maximum landing weight. The instructions to the content of this exercise read «If time allows, then with the landing». At the doing of the exercises 3.2.1-3.2.5 it is not possible to identify the signs of time shortage, as there are no comments by the instructor in relation to these elements of the program.*

Likewise at the doing of the LOFT exercise, depending on the established scenario, selected by the instructor, the intended TOW had been 42390 kg (URSS-URMM), or 42180 kg (URSS-URKK), or 43460 kg (URSS-URFF). In case of decision-making by the PIC to return to the departure aerodrome the situation may be simulated of the overweight landing, which is consistent with the Table of elements item 5.1.1 of the RRJ-95 Simulator Crew Line Operational Simulation (LOS) Manual in addition to the mandatory elements, stated in Chapter 2.3 of the RRJ-95 FFS Pilots' Drill and Check Manual (first half-year of 2018).

On February 22, 2019 in the progress of the FFS drill under the second day scenario at the practice of the LOFT exercise according to the established scenario of the flight en URKG-URSS route the intended TOW had been of the 42120 kg value. In case of the decision-making by the PIC to return to the departure aerodrome the simulation of the situation is possible of the overweight landing, which is compliant to the Table of elements item 5.1.1 of the RRJ-95 Simulator Crew Line Operational Simulation (LOS) Manual in addition to the mandatory elements, stated in Chapter 2.2. of the RRJ-95 FFS Pilots' Drill and Check Manual (first half-year of 2019).

The Aeroflot, PJSC OM does not integrate requirements for the pilot's practical skills, the Part D «Manual on the air personnel training» Chapter 6 «Flight Crewmembers Training» Section 6.1.12. «Requirements for the pilot's practical skills» is reserved for further use, that is not filled in.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the requirements for the OM content, the Manual on the Air Personnel Training Part D, namely, including the necessity to integrate «the detailed data on the aircraft flight crewmembers training program according to item 5.84 of these Regulations» are determined by FAR-128 item 5.12 sub-item г. At that FAR-128 item 5.84 sets out the requirements for the* *training content, its type and recurrence. The requirements for the practical skills are not explicitly stated, except for sub-item г), which «integrates training to acquire knowledge and skills, related to the visual and instrument flight patterns at the expected area of the flight performance, the limitation of human capacities ("human factor"), including the knowledge on hazards of their manifestation at the air operations, the prevention of the situations, resulting being beyond human capabilities, the prevention of errors and their correction, the transport of the dangerous goods by the aircraft».*

FAR-246 determine the following:

- as per item 24 «The operator shall ensure the maintenance of the required qualification at the operator's personnel through their recurrent training and education, the monitoring of knowledge and skills in accordance with the requirements of federal aviation regulations»;

- as per item 25 «The operator shall arrange the authorization of the aircraft flight crewmembers to perform their duties in accordance with the requirements of the federal aviation regulations and carry out: the arrangement and conduct of the training, drills, the monitoring of the skills and knowledge, provided for by the federal aviation regulations».

The requirement for skills is referred not to the assessment, but to the monitoring of the presence of skills at the pilot, prescribed by the aviation regulations, such as the skill of CRM, emergency and rescue proficiency, simulator proficiency, flight crew proficiency (flight crewmembers proficiency), the instructor's proficiency etc.

As the requirements for skills are stated in different Training Programs, for this reason the OM Part D item 6.1.12. «Requirements for the pilot's practical skills» had been reserved.

The table of remarks to the PIC by the supervisors at the training in accordance with the RRJ-95 Aircraft FCTP and into the recurrent simulator drills and checks

Date	The drill type	The stated remarks and recommendations[35]
19.07.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	The SOP procedures. The monitoring of the descent path.
18.07.2016 23.07.2016 25.07.2016 26.07.2016 27.07.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	The SOP performance order. The time monitoring at the preparation for landing. The landing estimation. The application of brakes. CRUISE BRIEFING. The performance of landing. To monitor engines power rating and the airspeed at proceeding by glideslope.
29.07.2016	The RRJ-95 aircraft check flight	The failure to maintain airspeeds as per the approach pattern
16.10.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 3 Task 3	- to monitor FAF; - to repeat actions at DH; - not to «go up» after DH
20.10.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 3 Task 3	- to repeat SOP by the legs of the flight; - to call out the parameters of the flight apart; … - the loss of airspeed at flare
20.11.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 3 Task 5	- not to allow a formal performance of the aircraft preflight inspection; - to repeat the order of actions in the windshear conditions; - to repeat the order of actions at the crosswind landing
24.11.2016	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 3 Task 5	- the briefing to cabin crew to avoid formal attitude; - to repeat the OM Chapter 2 «The basic principles of interaction in the crew»;

[35] This column cites the instructor remarks at the retained original text.

		- to repeat the approach airspeeds at the Moscow air zone
07.02.2017	The RRJ-95 aircraft check flight	Not to allow the formal performance of the briefings, to focus attention on peculiarities and variables.
28.04.2017	The RRJ-95 aircraft check flight	The SOP item 2.15 remarks «Preparation for landing»
14.09.2017	Recurrent drill and check at the SSJ-100 FFS	- the lack of critical evaluation of the flight parameters in terms of «the stabilized approach» at the ILS approach; - the lack of Call Outs at the ILS approach
08.11.2017	The RRJ-95 aircraft check flight	- the non-meeting the SOP at their performance by the legs of the flight; - the ill-considered performance of the briefings by the stages of the flight; - theoretical knowledge of the Required Estimated Distance; - the lack of the wind information monitoring at takeoff and landing
04.03.2018	Recurrent drill and check at the SSJ-100 FFS	- the late detection of the windshear; - the unilateral decision-making, without considering the opinion of the F/O; - the formal doing of a checklist
30.08.2018	Recurrent drill and check at the SSJ-100 FFS	- the ill-timed detection of W/S; - does not read FMA at G/A; - the preparation for NPA landing; - the erroneous actions on the initiation of the Spec. EO S/D performance; - the CRM requires the understanding of the failure; - not to forget about potential time shortage; - the lack of standard Call Outs, Normal Checklist at every leg

09.04.2019	The SSJ-100 FFS training under the RRJ-95 Aircraft FCTP	- the flight parameters monitoring at the final approach (the lack of the call outs standards on the deviations); - the emergency descent procedure: the PNF actions were not been fully performed (seat belt); - the commands and standard phrases do not meet the SOP

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the third column of the Table contains not only remarks, but the recommendations as well. The ICAO Doc 9859 AN/474 (Safety Management Manual) reads that humans will commit errors regardless of the level of technology used, the level of training or the existence of regulations, processes and procedures, an important goal then is to set and maintain defenses to reduce the likelihood of errors and reduce the consequences of errors when they do occur. To effectively accomplish this task, errors must be identified, reported and analyzed so that appropriate remedial actions can be taken, which is one of the main objectives of the instructors and examiners at the training and qualification checks on the simulator or in line conditions. Thus, the introduction of comments/remarks and recommendations into the flight documentation of pilots is a normal practice, the purpose of which is to advance the aviation safety.*

The leaves status

In the period from December 5 to December 9, 2016, the pilot was granted a leave with a total duration of 5 calendar days out of the annual basic paid leave.

In the period from December 30, 2016 to January 13, 2017 the pilot was granted a leave with a total duration of 7 calendar days out of the annual basic paid leave.

In the period from March 3 to March 11, 2017 the pilot was granted a leave with a total duration of 7 calendar days out of the annual basic paid leave.

In the period from June 15 to June 28, 2017 the pilot was granted a leave with a total duration of 14 calendar days, of which 9 days out of the annual basic paid leave, 5 days out of the additional paid leave.

In the period from July 24 to August 19, 2017 the pilot was granted a leave with a total duration of 27 calendar days out of the additional paid leave.

In the period from October 8 to October 14, 2017 the pilot was granted a leave with a total duration of 7 calendar days out of the additional paid leave.

In the period from December 1 to December 14, 2017 the pilot was granted a leave with a total duration of 14 calendar days of which 12 days out of the annual basic paid leave, 2 days out of the additional paid leave.

In the period from March 5 to March 19, 2018 the pilot was granted a leave with a total duration of 14 calendar days out of the annual basic paid leave.

In the period from May 21 to June 3, 2018 the pilot was granted a leave with a total duration of 14 calendar days of which 3 days out of the annual basic paid leave, 11 days out of the additional paid leave.

In the period from July 26 to August 8, 2018 the pilot was granted a leave with a total duration of 14 calendar days out of the additional paid leave.

In the period from October 15 to October 21, 2018 the pilot was granted a leave with a total duration of 7 calendar days out of the additional paid leave.

In the period from January 15 to January 31, 2019 the pilot was granted a leave with a total duration of 17 calendar days of which 7 days out of the annual basic paid leave, 10 days out of the additional paid leave.

According to the employment contract # 431 of April 25, 2016 item 7.2: *«The employee is granted with an annual basic paid leave of 28 calendar days, as well as with the additional paid leave, the duration of which depends on the flying time in the working year (the Ministry of Civil Aviation Order # 50 of March 13, 1986*»

Note: *The Appendix to the Ministry of Civil Aviation Order # 50 of March 13, 1986*

The additional leave for working in special conditions is granted to employees in excess of the basic leave of 12 working days of the following duration:

1. The flight crew personnel employees, flight attendants and the aircraft flight operators with the flying time in a working year of:

from 50 to 100 hrs 6 working days,

from 101 to 200 hrs 12 working days,

from 201 to 300 hrs 18 working days,

from 301 to 400 hrs 24 working days,

from 401 to 500 hrs 30 working days,

over 500 hrs 36 working days.

Over the period of April 27, 2016 – May 5, 2019 the PIC had been employed by Aeroflot, PJSC for three full working years, at that the flying time in the first working year amounted to 368 hrs, 563 hrs through the second one, 616 hrs in the third one. Correspondingly the duration of the additional leave for working in special conditions should have amounted to 24 working days over the first year and 36 working days over the second and third one each.

As for the indicated period the PIC had been granted with 147 calendar days of the leave, out of which 64 days had been of the annual basic paid leave and 83 days of the additional one.

The periods of the additional leave integrated 16 days-off, thus, the pilot had been granted with 67 working days.

Thus, as of May 6, 2019 the unused days of the annual basic leave amounted to 20 calendar days, on the additional paid leave to 29 working days.

Note: *According to the position of the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, 16 days-off are* ***the calendar days****, but with that they are not* ***non-working holidays****, and as per the Russian Federation Labor Code Article 120 «The calculation of the duration of the annual paid leaves»: «The duration of the annual basic and additional paid leaves shall be calculated* ***in calendar days*** *and is not subject to the maximum limit restriction.* ***The non-working holidays****, occurring within the period of the annual basic or the annual additional paid leave are not included among the calendar days of the leave (as amended by Federal Law # 90-ФЗ of June 30, 2006).*

At the calculation of the total duration of the annual basic leave the additional paid leaves shall be summed up with the annual basic paid leave».

Consequently, as of May 5, 2019 the unused days of the annual basic leave amounted to 20 calendar days and 13 ***calendar days*** *of the additional paid leave.*

The results of undergoing of the annual medical examinations and recurrent medical checks

On April 19, 2016 he had been subject to medical examination at the Aeroflot, PJSC health center MFEC, having been declared fit for the air operations as the line pilot. He was issued the I class medical certificate BT # 224649, valid till April 19, 2017.

On October 10, 2016 the Aeroflot, PJSC medical center doctor had conducted the six-month medical check, the pilot had been authorized for air operations as the line pilot.

On April 20, 2017 he had been subject to medical examination at the Aeroflot, PJSC medical center MFEC, having been declared fit for the air operations as the line pilot. He was issued the I class medical certificate BT # 020733, valid till April 20, 2018.

On October 19, 2017 the Aeroflot, PJSC medical center doctor had conducted the six-month medical check, the pilot had been authorized for air operations as the line pilot.

On April 19, 2018 he had been subject to medical examination at the Aeroflot, PJSC medical center MFEC, having been declared fit for the air operations as the line pilot. He was issued the I class medical certificate BT # 052858, valid till April 19, 2019.

On October 24, 2018 the Aeroflot, PJSC medical center doctor had conducted the six-month medical check, the pilot had been authorized for air operations as the line pilot.

On April 18, 2019 he had been subject to medical examination at the Aeroflot, PJSC medical center MFEC, having been declared fit for the air operations as the line pilot. He was issued the I class medical certificate BT # 100782, valid till April 18, 2020.

First officer

Position	**The RRJ-95 first officer**
Sex	Male
Age	36
Education	Sasovo Flight College for Civil Aviation, the Ulyanovsk institute for civil aviation, FSFEI HE branch in 2016 in *Flight Operation of Aircraft*, qualified as *a pilot*.
The RRJ-95 aircraft transition training	Aeroflot Aviation School, PPEI (Moscow), diploma # 00905 of June 14, 2018
Pilot’s license	CPL # 0079551, issued by the FATA Komi Interregional Territorial Directorate on July 26, 2018
Type ratings	Самолет RRJ-95 Co-pilot. Полеты по правилам полетов по приборам – самолет/RRJ-95 aircraft first officer. The IFR flights – airplane
Medical certificate	Issued on June 15, 2018, the Aeroflot, PJSC medical center, the I class medical certificate BT # 053484, valid till June 15, 2019
Weather minimum	ICAO CAT III 15 x 175 m
Total flying time, of which at: Cessna-172 L-410	774 hrs 37 min 105 hrs 45 hrs
The RRJ-95 aircraft flying time	624 hrs 37 min
Flying time over last 30 days	70 hrs 13 min
Flying time over last 3 days	05 hrs 24 min

Flying time on the day of the accident	00 hrs 46 min[36]
Total duty time on the day of the accident	02 hrs 12 min
The intervals in flights over the last year	None
The date of the last proficiency check	On March 20, 2019, the Aeroflot, PJSC flight instructor-examiner, the excellent mark
Land emergency and rescue training	On February 25, 2019 at the Aeroflot, PJSC Air Personnel Training Department
Water emergency and rescue training	July 19, 2018 at the Aeroflot, PJSC Air Personnel Training Department
Simulator training	December 11, 2018 at the Aeroflot, PJSC Air Personnel Training Department
The professional advanced training	On December 3, 2018 – the disciplines of the second half-year of 2018 On June 25, 2018 – the disciplines of the first half-year of 2018
The spring-summer period authorization	April 5, 2019
The CRM training	Certificate # 102344 of June 26, 2018
The preliminary training for flights, based on specific areas, routes and aerodromes	On July 3, 2018 at the Aeroflot, PJSC Air Personnel Training Department, Sheremetyevo
The preflight preparation	On May 5, 2019, at Sheremetyevo airport under the authority of the PIC
The crew rest	More than 46 hrs, at home
Preflight medical check	At the Aeroflot, PJSC crew preflight medical check unit at 12:57 on May 5, 2019
Air accidents and incidents in the past	None

[36] As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the flying time of the aircraft crewmembers is logged from the point of the engines startup. The time from the takeoff initiation till the air accident had amounted to 28 min approximately.

The English language proficiency	ICAO Level 4, valid till: May 22, 2019 (as in the CPL # 0079551); May 19, 2020 (as in the certificate by the Aeroflot Aviation School, PPEI)

The F/O graduated from Sasovo flight college for civil aviation, Ulyanovsk Institute for civil aviation, FSFEI HE branch in 2016 and had been issued the diploma # 106224 1449446 of May 27, 2016 in *Flight Operation of Aircraft*, qualified as *a pilot*. The total flying time over the period of studies had amounted to 150 hrs on Cessna-172 and L-410.

Over May 23, 2017 – June 9, 2017 he underwent the training at the Aeroflot Aviation School, PPEI (г. Moscow) (the air training center certificate # 202, issued by FATA on March 15, 2017) under the Russian Federation Civil Aviation Aircraft Flight Crewmembers Training to perform international air operations advanced training program (approved by FATA on March 4, 2016) in the amount of 126 teaching hours. With the end of the training he was issued the certificate # 026679 of June 9, 2017.

Over July 3, 2017 – August 1, 2017 he underwent the training at the Aeroflot Aviation School, PPEI (Moscow) (the air training center certificate # 202, issued by FATA on March 15, 2017) under the Aviation Technical English Language for the Flight Personnel advanced training program (approved by FATA on March 4, 2016) in the amount of 130 teaching hours. On the completion of the training he was issued the certificate # 030282 of August 1, 2017.

The selection commission on the employment of the flight personnel to work at Aeroflot, PJSC had made the decision (the minutes of meeting # 149 of January 31, 2018): *«to recommend for the A320 aircraft transition training with the subsequent employment by Aeroflot, PJSC»*. Meanwhile, as per the Aeroflot, PJSC deputy general manager – air operations director's recommendation the pilot had been recommended for the supplementary training and the professional additional training under the SSJ-100 Aircraft F/O program.

On February 12, 2018 the candidate (F/O), selected by the decision of the commission on the flight personnel selection to work at the Aeroflot, PJSC on the position of the flight crew training division, submitted the application to the Aeroflot, PJSC deputy general manager – air operations director with the request for consent for the SSJ-100 aircraft transition training. The application had been coordinated with the flight crew training division commander, the SSJ-100 aircraft air division, the Safety Management department director, the Air Operations department director.

Over February 12 – February 14, 2018 he underwent the training at the Aeroflot Aviation School, PPEI under the Dangerous Goods Transportation by Aircraft advanced training program (the ICAO CAT 10) (approved by FATA on August 14, 2017) in the amount of 20 teaching hours. On the completion of the training he was issued the certificate # 042775 of February 14, 2018.

Over February 15 – February 16, 2018 he underwent the training at the Aeroflot Aviation School, PPEI under the Aviation Security advanced training program (the initial and advanced training for the flight crewmembers) (approved by FATA on March 3, 2016) in the amount of 16 teaching hours. On the completion of the training he was issued the certificate # 045143 of February 16, 2018.

Over February 20 – May 20, 2018 he underwent the training at the Aeroflot Aviation School, PPEI under the Training of Flight Personnel With No Experience of the Operation of the Civil Aviation Aircraft, Equipped With The Display (Digital) Indication For the Other (New) Aircraft Types Transition Training advanced training program (approved by FATA on March 4, 2016) in the amount of 107 teaching hours. Following the end of the training he was issued the certificate # 053220 of May 20, 2018.

Over March 3 – March 7, 2018 he underwent the training at the Aeroflot Aviation School, PPEI under the Flight Crewmembers Emergency and Rescue Training Into the RRJ-95 (SSJ-100) Aircraft Transition Training advanced training program (approved by FATA on February 10, 2016) in the amount of 18 teaching hours. On the completion of the training he was issued the certificate # 046457 of March 7, 2018.

Over March 12 – June 14, 2018 he underwent the professional training as a F/O at the Aeroflot Aviation School, PPEI (Moscow) under the RRJ-95 Aircraft Flight Personnel Transition Training professional transition training program (approved by FATA (Rosaviatsiya) Flight Operations Department head on February 15, 2016) (hereinafter referred to as the Program) in the amount of 282 teaching hours.

Prior to the new aircraft type transition training, as per the FAR ME CA-2002 provisions the pilot should have undergone the psychological examination. According to the available documents the pilot had been subject to the psychological examination at the Aeroflot, PJSC medical center MFEC not earlier than on June 15, 2018, that is after the actual completion of the transition training.

As per the explanatory note to the Program the pilot had been authorized for training under the Program course. At that the investigation team points out that there are apparent contradictions between two items of the Explanatory note. The F/O met the Categories of listeners' item, but did not meet the Level of Preliminary Training item, as he had not been issued the civil aviation ATPL. In this way, the investigation team had not been able to unequivocally assess the reasonableness of the pilot's authorization to undergo the Program.

Note: *The explanatory note to the RRJ-95 Aircraft Flight Personnel Transition Training professional transition training program.*

…

The categories of listeners: *line and commercial pilots, having obtained the local qualification commission recommendation, drawn up as per the established procedure.*

The level of the preliminary training: *the experience in the aircraft air operations, the earlier issued valid ATPL for civil aviation, the English language proficiency, sufficient to work with the operational documentation and to interact in the flight crew.*

The duration of training: *43 training days:*

- theoretical training out of 22 training days;

- simulator training out of 21 days.

…

The Program curriculum:

1. Theoretical training out of 170 teaching hours;

2. Simulator training out of 112 teaching hours (84 astronomical hours).

According to the Program curriculum, the simulator/FFS training session 5 provides for the performance of the F/CTL DIRECT MODE abnormal procedure.

Note: *The RRJ-95 Aircraft Flight Personnel Transition Training professional transition training program*

The Program curriculum.

…

2. Simulator training.

…

FULL FLIGHT SIMULATOR 5.

…

«The climb and cruise flight:

…

Emergency: F/CTL DIRECT MODE;

The piloting in simplified and minimum modes;

A series of stalls in different configurations;

…

Descent and approach:

The ILS approach with the subsequent circle-to-land maneuvering;

Go-around;

Visual circling flight;

Go-around;

Visual circling flight;

Crosswind landing».

According to the Training Summary Record, on May 29, 2018 the pilot underwent the FFS 5 training. Still as for the available documents it is impossible to figure out in what actual amount and at what parameters (the meteorological conditions, the airplane weight, etc.) the FBWCS DIRECT MODE training had been carried out.

On the completion of the training the diploma # 00905 of June 14, 2018 had been issued.

As per the employment contract # 946 of May 23, 2018 from June 1, 2018 the pilot had been employed at the Air Operations department flight crew training division. The relevant Order by the Human Resources department director (# 7748/л of May 28, 2018) on the pilot's employment had been issued as well.

Over June 19 – June 26, 2018 he underwent the training at the Aeroflot, PJSC Flight Personnel Training department under the Flight Personnel Human Factor and CRM (approved by FATA on May 28, 2015) in the amount of 24 teaching hours. On the completion of the training he was issued the certificate # 102344 of June 26, 2018.

Following the completion of the flight crew training program for the performance-based navigation (PBN) flights, by the SSJ-100 aircraft air division commander Order # 241 of July 19, 2018 he had been authorized to perform flights with the use of performance-based navigation (PBN) aboard the RRJ-95 aircraft.

Following the completion of the flight crew training program for flights in RVSM airspaces (the Russian Federation Ministry of Transport Order # НА-56-р of February 20, 2001), by the SSJ-100 aircraft air division commander Order # 242 of July 20, 2018 he had been authorized for the RVSM flights in the airspace of Russia, Europe, and Asia.

According to the Aeroflot, PJSC deputy general manager – air operations director Order # 125.11/1-1461/у of July 27, 2018 (pursuant to the report of the SSJ-100 aircraft air division commander with internal # 150.16/4976 of July 25, 2018) the pilot had been authorized for the commissioning as the RRJ-95 aircraft F/O from July 28, 2018 to November 20, 2018 under Variant 6, compliant to the Aeroflot, PJSC RRJ-95 Aircraft FCTP with the assignment of the ICAO CAT I weather minimum, as well as the assignment of the SSJ-100 aircraft air division air squadron # 2 commander instructor to him.

Actually, he had undergone the training for the flights performance as the F/O over July 3, 2018 – October 10, 2018 under Variant 6 of the Aeroflot, PJSC RRJ-95 Aircraft FCTP (Third edition) revision 8 (it had become effective from May 14, 2018) (compliant to the program, the training under Variant 6 is arranged to the pilots with no experience of air operations aboard the aircraft of MTOW ≥ 5700 kg, the civil aviation flight educational institutions graduate pilots).

Variant 6 of training for flights performance (up to the aircraft PIC) provides for the training in full by:

Section 1 «The pilot’s training for the solo flights as the F/O»;

Section 2 «The F/O’s training for commissioning as the aircraft PIC» (the flying time under Section 1 Tasks 2÷4 may be credited to the total flying time (the number of flights and the time) under Section 2 Task 1);

Section 3 «The training for flights as an aircraft PIC».

The F/O started the ground training under Program 1 Section 1 Task 1 on July 3, 2018, that is before the issuance of the order on his authorization for commissioning as a F/O.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, according to OM Part A item 5.2.5. (2) the objective of the commissioning is a consolidation of the practical skills and the proficiency enhancement of the flight specialist in the progress of the flight drill at the line training. Thus, the commissioning is a practical stage of the training, by the start of which the pilot is issued the respective order for commissioning as the aircraft PIC with the assignment of the flight instructor to him.*

According to the Flight Training as a F/O form (issued by the SSJ-100 aircraft air division commander on July 3, 2018, compliant to the Program 1 Appendix 1.1-1.), the ground training had been conducted by different instructors over July 3 – July 18, 2018, the ground training total time had amounted to 14 hrs[37]. The assigned instructor had not been involved in the ground training. The conclusion by the head of the Safety management department of July 18, 2018: *«Authorized for the drill under Section 1 Task 2 Exercise 1».*

The pilot proceeded to the Program 1 Section 1 Task 1A pre-commissioning flight drill on July 25, 2018.

According to the Pilot’s Flight Drill Prior to Commissioning form (issued by the SSJ-100 aircraft air division commander on July 25, 2018, compliant to the Program 1 Appendix 1.1-1.), the drill under exercise 1 «The flight drill at the simulator» in the amount of the ZFTT session by

[37] It meets the RRJ-95 Aircraft FCTP provisions.

a special method had been completed on July 25, 2018 (similarly before the issuance of the order on the commissioning), conducted as well not by the assigned instructor, the good mark, the time of 2 hrs[38]. The instructor's conclusion: *«Authorized for drill under Exercise 2».*

The drill under Exercise 2 «The line flight drill aboard the aircraft» with the practice of the piloting skills aboard the real aircraft by a special method had been completed without the involvement of the assigned instructor, the 6 approaches[39] are indicated, the good mark. The instructor's conclusion of August 7, 2018: *«May undergo the training for solo flights».*

According to the form (the Program1 Appendix 1.1-2.), the exercise 1 «The line drill as an observer pilot» of the Section 1 Task 2 had been completed by the pilot over July 30, 2018 – August 1, 2018 in the amount of 5 flights (the duration of 10 hrs 53 min)[40]. Three different pilots had been involved in the drill as the instructors. The conclusion by the senior flight instructor, the Flight Standards group head of August 1, 2018: *«Authorized for the drill under Task 2 Exercise 2».*

The drill under Exercise 2 «The line drill as the F/O» had been carried out over August 8 – October 1, 2018. 78 line flights[41] had been performed (the duration of 143 hrs 10 min). Apart of the assigned instructor 8 more different instructors had been involved in the drill. The conclusion by one of the instructors of September 28, 2018: *«Authorized for check under Task 3».*

Two check flights[42] (the duration of 05 hrs 52 min) under Task 3 had been completed on October 2, 2018 with the SSJ-100 aircraft air division air squadron # 3 commander, the flight instructor-examiner, the conclusion of October 2, 2018: *«May perform flights as the RRJ-95 aircraft F/O in an assigned crew».* The results of the check are drawn up by the instructor in the Pilot's Qualification Check Report of October 2, 2018 (compliant to the Aeroflot, PJSC OM Part A Appendix 5.9.7.1.), the good general mark.

On the recommendation by the instructor-examiner of October 2, 2018, the Local Qualification Commission decision of October 9, 2018 (the minutes of meeting # 41) and according to the SSJ-100 aircraft air division commander Order # 334 of October 11, 2018, due to the completion of the flight training program, compliant to the RRJ-95 Aircraft FCTP, from October 11, 2018 the pilot had been authorized for solo flights as the RRJ-95 aircraft F/O in an assigned crew under ICAO CAT I weather minimum (60x550, takeoff of 200 m at high-intensity

[38] It meets the RRJ-95 Aircraft FCTP provisions
[39] From 4 to 6 approaches according to the RRJ-95 Aircraft FCTP
[40] 6 flights according to the RRJ-95 aircraft FCTP
[41] From 50 to 80 flights according to the RRJ-95 aircraft FCTP.
[42] It meets the RRJ-95 aircraft FCTP provisions.

lighting). To perform the airline flights the pilot by the same Order had been assigned to the SSJ-100 aircraft air division air squadron # 1 PIC[43].

According to the Aeroflot, PJSC deputy general manager – air operations director Order # 125.11/1-690/л of October 11, 2018, he had been transferred the Aeroflot, PJSC SSJ-100 aircraft air division air squadron # 1 F/O.

According to the SSJ-100 aircraft air division commander Order # 354 of October 19, 2018 he had been authorized for solo flights as the RRJ-95 aircraft F/O under ICAO CAT III A weather minimum (15x175, takeoff of 150 m at high-intensity lighting).

According to the SSJ-100 aircraft air division commander Order # 398 of November 20, 2018, due to the operational necessity to perform the airline flights the pilot had been assigned to another SSJ-100 aircraft air division air squadron # 1 PIC (ATPL # 0082074 issued on December 10, 2018).

According to the SSJ-100 aircraft air division commander Order # 94 of March 12, 2019, due to the operational necessity to perform the airline flights the pilot had been assigned to the new SSJ-100 aircraft air division air squadron # 1 PIC (ATPL # 0099072 issued on May 29, 2019).

As per the Training for Flights in an Unassigned Crew form (issued by the SSJ-100 aircraft air division commander on October 11, 2018, compliant to the Program 1 Appendix 1.3-1.), the training under Exercise 1 «The F/O's training for flights in an unassigned crew» of the Program 1 Section 1 Task 4 had been carried out over October 12, 2018 – April 14, 2019, the pilot had performed 183 flights (the duration of 303 hrs 05 min)[44]. When doing this exercise the flights had been performed with four different PICs. The conclusion by the SSJ-100 aircraft air division commander of April 22, 2019: *«The exercise 1 has been completed, authorized for check flights».*

The check flight[45] (07 hrs 02 min) under exercise 2 «Check flight» of Program 1 Section 1 Task 4 had been performed on April 19, 2019, the conclusion by the instructor of April 19, 2019: *«May perform flights aboard the RRJ-95 airplane as a F/O in an unassigned crew».*

According to the SSJ-100 aircraft air division commander Order # 148 of April 22, 2019, he had been authorized to perform flights in an unassigned crew.

On December 10, 2018 under the authority of the simulator instructor the drill on the SSJ-100 FFS had been arranged to the pilot at the Aeroflot, PJSC Flight Personnel Training department,

[43] According to item 4.5.1. «The flight crewing to aircraft» of the Aeroflot, PJSC OM Part A Chapter 4 Section 4.5, at the crewing it is taken into account that one of the pilots in the minimum crew should have sufficient flight experience aboard this aircraft type on the completion of the transition training and commissioning (the authorization for solo flights) (this aircraft type flying time of at least 200 hrs, and in case the F/O had undergone the training under the commissioning program Variant V or VI, he shall perform at least 100 flights additionally aboard this aircraft type).

[44] From 300 to 500 hrs according to the RRJ-95 Aircraft FCTP.

[45] 2 hrs (at FFS) or 2 flights according to the RRJ-95 Aircraft FCTP.

compliant to the RRJ-95 FFS Pilots' Drill and Check Manual (over the period of the second half-year of 2018). On December 11, 2018 under the authority of the SSJ-100 aircraft air division air squadron # 1 commander the drill and check had been carried out at the SSJ-100 FFS.

The performance of the F/CTL DIRECT MODE abnormal procedure is provided for by the scenario of the exercise 4.1.23 «STALL RECOVERY» and exercise 4.1.24 «Unreliable Air Speed Indications » (compliant to the Manual, the exercises had been carried out on the first day of the drill of December 10, 2018). The scenarios to these exercises do not imply the performance of go-around in DIRECT MODE. The pilot's record sheet of the scheduled drills reads the completion of the drill under the scenario of the aircraft recovery out of approach to stall and stall modes. As for the drill assignment and the scheduled drills record sheet it is impossible to make the conclusion on the actual doing of the exercise 4.1.24 «Unreliable Air Speed Indications». The System Failures item 7 of the Pilots' Simulator Drill and Check form (the Aeroflot, PJSC OM Part A Appendix 5.9.8.1.) does not read the entry on the performance of the drill in DIRECT MODE.

Note: *The RRJ-95 FFS Pilots' Drill and Check Manual (approved by the Aeroflot, PJSC deputy general manager – air operations director on May, 22, 2018 (for the instructors, over the period of July-December of 2018))*

4.1.23 STALL RECOVERY (PF-CM 1)

The settings (of the simulator) to practice the exercise: … DIRECT MODE

….

The reminder (guidance) to the instructor: …

- To activate the DIRECT MODE. Maintain altitude and idle up to the trigger of the STALL, STALL, STALL warning. To demonstrate maximum AOA and pitch attitudes (the actions on the recovery afterwards).

4.1.24 Unreliable airspeed indications

The settings to practice the exercise: IOS-MALF'S NAVIGATION SYSTEM (34) – 3 PITOT BLOCK

The reminder (guidance) to the instructor:

…

- The failure is introduced after takeoff;

- Perform the flight from takeoff to landing.

The investigation team request to provide more detailed data on the exercises (modes), actually practiced at the FBWCS operation in DIRECT MODE, had not been responded.

On December 11, 2018 under the authority of the instructor-examiner the drill and the piloting technique check to perform flights by the ILS raw data had been arranged to the pilot at the SSJ-100 FFS, compliant to the RRJ-95 FFS Pilots' Drill and Check Manual.

The record sheet of the pilot's scheduled drills at the simulator reads the completion of this drill. The result of the piloting technique by ILS raw data check (the good mark) is introduced to column 3.1. of the Simulator Check table of the Pilots' drill and Check at the Simulator form.

By the SSJ-100 aircraft air division commander order # 124 of April 5, 2019 as having completed full training under the seasonal training program at the Aeroflot PJSC Flight Personnel Training Department, he was authorized to perform flights in the spring-summer period of 2019 under the earlier established weather minimum.

The table of remarks to the F/O by the supervisors at the training in accordance with the RRJ-95 Aircraft FCTP and into the recurrent simulator drills and checks

Date	The drill type	The stated remarks and recommendations[46]
25.07.2018	Flight drill at the SSJ-100 FFS	The unstable glide angle
07.08.2018	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	- no Vy deceleration at the landing; - repeat SOP!!!
09.08.2018 19.08.2018 24.08.2018 27.09.2018	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	To repeat the maximum deviations on final To repeat the rules for the error correction at the landing. High flare. The ballooning at the landing. To repeat the rules of hard landing prevention
29.08.2018	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	The landing to the right off the centerline with the right roll of 0.46°, this is not an exceedance, but seek to land level strictly along the axis of the runway
30.08.2018	Line drill under the RRJ-95 Aircraft FCTP Program 1 Section 1 Task 2 Exercise 2	Focus on: - the sidestick inputs in roll on final at no turbulence and no drift angle; - the landing on the runway centerline with no off- centerline shift
11.12.2018	Scheduled drill and check at the SSJ-100 FFS	- the piloting by ILS RAW DATE – heading ± 1 dot, glideslope ± 1 dot; - the landing at the crosswind max. to the left off the centerline 1/3 RWY, early decrab; - maintenance of V + 14 /–8 KTS; - the actions at the encounter of Windshear – to repeat, not to allow «over speed»; - the actions at go-around to learn by heart

[46] This column cites the instructor remarks at the retained original text.

20.03.2019	Qualification check, the SSJ-100 aircraft	The computation, monitoring and timely correction of the descent profile. Into further flights to work out the maintenance of the straight-line descent profile from DH up to the initiation of flare.

Note: *As evidenced by the representatives of the Aeroflot, PJSC management and command and flight personnel, having been the members of the air operations group to the investigation, the third column of the Table contains not only remarks, but the recommendations as well. The ICAO Doc 9859 AN/474 (Safety Management Manual) reads that humans will commit errors regardless of the level of technology used, the level of training or the existence of regulations, processes and procedures, an important goal then is to set and maintain defenses to reduce the likelihood of errors and reduce the consequences of errors when they do occur. To effectively accomplish this task, errors must be identified, reported and analyzed so that appropriate remedial action can be taken, which is one of the main objectives of the instructors and examiners at the training and qualification checks on the simulator or in line conditions. Thus, the introduction of comments/remarks and recommendations into the flight documentation of pilots is a normal practice, the purpose of which is to advance the aviation safety.*

The leaves status

According to the employment contract # 946 of May 23, 2018 item 4.2: «*The employee is granted with an annual basic paid leave of 28 calendar days, as well as with the additional paid leave, the duration of which depends on the flying time in the working year (the Ministry of Civil Aviation Order # 50 of March 13, 1986*»

Note: *The Appendix to the Ministry of Civil Aviation Order # 50 of March 13, 1986*
The additional leave for working in special conditions is granted to employees in excess of the basic leave of 12 working days of the following duration:
1. The flight crew personnel employees, flight attendants and the aircraft flight operators with the flying time in a working year of:
from 50 to 100 hrs 6 working days,
from 101 to 200 hrs 12 working days,
from 201 to 300 hrs 18 working days,
from 301 to 400 hrs 24 working days,
from 401 to 500 hrs 30 working days,

over 500 hrs 36 working days.

As per the leaves schedule for 2019, approved by the Air Operations department director on December 7, 2018, the F/O had been scheduled with the leave out of 12 calendar days from May 1, 2019. On April 22, 2019 the F/O had submitted the application, addressed to the Aeroflot, PJSC general manager, on the annual paid leave transfer for May 13, 2019 for family reasons. The application had been coordinated with the head of division (the SSJ-100 air division commander) and the responsible for the leave administration.

Over the working period of June 1, 2018 – May 31, 2019 the pilot logged the flying time of more than 500 hrs. Accordingly, the duration of the additional leave for working in special conditions should have amounted of 36 working days. Likewise, the pilot should have been granted with 28 calendar days of annual basic paid leave.

Over the mentioned working period the F/O had not been on the leave. Even taking into account 12 calendar days of the annual paid leave that had been scheduled to the pilot from May 13, 2019, as far as June 1, 2019 it had been impossible to fully arrange the basic and additional leaves.

The results of undergoing of the annual medical examinations and recurrent medical checks

On November 10, 2015 he had been subject to examination at the Sasovo flight college for civil aviation, Ulyanovsk Higher Aviation College (Institute) for civil aviation, FSFEI HE branch MFEC, having been declared fit for the air operations as the commercial aviation pilot (the airplane and the helicopter), the I class medical certificate PA # 198062, valid till November 10, 2016.

On April 25, 2016 the Sasovo flight college for civil aviation, Ulyanovsk Higher Aviation College (Institute) for civil aviation, FSFEI HE branch air division doctor had conducted the six-month medical check, the pilot had been authorized for air operations.

On June 21, 2017 he had been subject to examination at the MFEC of the Regional Technical Center for Aviation Information, Certification, Communications, FSUE medical unit, having been declared fit for the air operations as the commercial aviation pilot, the I class medical certificate PA # 007922, valid till June 21, 2018.

On June 15, 2018 he had been subject to examination at the Aeroflot, PJSC medical center MFEC, having been declared fit for air operations as the commercial aviation pilot, the I class medical certificate BT # 053484, valid till June 15, 2019.

On December 13, 2018 the Aeroflot, PJSC medical center doctor had conducted the six-month medical check, the pilot had been authorized for air operations as the commercial aviation pilot.

1.5.2. Cabin crew

Position	**The RRJ-95 chief F/A**
Sex	Female
Age	27
Class	1
Education	Higher
The RRJ-95 transition training	Over March 16 – June 9, 2015, at the Aeroflot Aviation School, NSEPI SPE under the A-320, RRJ-95, A-330 Aircraft Cabin Crewmembers Initial Training program
Civil aviation F/A license, validity	# 0010526, issued permanent on September 8, 2015 by North-Western FATA Interregional Territorial Department
Valid authorization as per the aircraft types	A-320 25.09.2015, A-330 25.02.2016, B-737 01.12.2017, RRJ-95 28.04.2016
Valid chief F/A authorization	A-320 06.03.2017, B-737 07.12.2017, RRJ-95 19.10.2017
Advanced training	02.04.2019
Chief F/A advanced training	04.04.2019
The B-737 NG aircraft check flight	17.07.2018, at the Aeroflot, PJSC Onboard Passenger Service Department Flight Safety Inspection, the excellent mark
The RRJ-95 aircraft check flight	19.10.2017, at the Aeroflot, PJSC Onboard Passenger Service Department Flight Safety Inspection, the excellent mark
Water emergency and rescue training	01.04.2019 at the Aeroflot Aviation School, PPEI
Land emergency and rescue training	02.04.2019 at the Aeroflot Aviation School, PPEI
Spring-summer period authorization	29.04.2019
Medical certificate	January 26, 2015, II class medical certificate PA # 175773, valid till January 26, 2020

Total flying time	2644 hrs 51 min
The RRJ-95 flying time	150 hrs 51 min
Flying time over the last month	78 hrs 38 min
Flying time on the day of the accident	00 hrs 28 min
Preflight rest	More than 48 hrs, at home
Total duty time on the day of the accident	02 hrs 20 min
Preflight medical check	At the Aeroflot, PJSC crew preflight medical check unit on 05.05.2019
Air accidents and incidents in the past	None

According to the employment contract # 729 of September 15, 2015 and the Aeroflot, PJSC customer service deputy general manager Order # 10720/л of September 21, 2015 she was employed at the Aeroflot, PJSC Onboard Passenger Service Department cabin crew division # 5 on the position of the F/A.

Position	**The RRJ-95 F/A**
Sex	Female
Age	34
Class	3
Education	Secondary
The RRJ-95 transition training	Over July 16 – August 1, 2012 at the Aeroflot Aviation School, NSEI under the A-320, RRJ-95 Aircraft Cabin Crewmembers Transition Training program
The civil aviation F/A license, validity	V БП # 018529, issued permanent on August 3, 2011 by the FATA Central Interregional Territorial Directorate Territorial Qualification Commission
Valid authorization as per the aircraft types	A-320 11.08.2012, RRJ-95 23.08.2016
Advanced training	15.02.2018
The A-320 check flight	07.12.2018, at the Aeroflot, PJSC Onboard Passenger Service Department Flight Safety Inspection, the excellent mark

The RRJ-95 check flight	23.08.2016, at the Aeroflot, PJSC Onboard Passenger Service Department Flight Safety Inspection, the excellent mark
Water emergency and rescue training	15.02.2018 at the Aeroflot Aviation School, PPEI
Land emergency and rescue training	14.02.2019 at the Aeroflot Aviation School, PPEI
Spring-summer period authorization	29.04.2019
Medical certificate	February 10, 2016, II class medical certificate PA # 223701, valid till February 10, 2021, issued by the Aeroflot, PJSC medical center MFEC
Total flying time	2466 hrs 21 min
The RRJ-95 flying time	520 hrs 26 min
Flying time over the last month	43 hrs 58 min
Flying time on the day of the accident	00 hrs 28 min
Preflight rest	More than 12 hrs at home
Total duty time on the day of the accident	02 hrs 20 min
Preflight medical check	At the Aeroflot, PJSC crew preflight medical check unit on 05.05.2019
Air accidents and incidents in the past	None

According to the employment contract # 274 of July 5, 2012 and the Aeroflot, PJSC customer service deputy general manager Order # 5665/л of July 10, 2012 she was employed at the Aeroflot, PJSC Onboard Passenger Service Department cabin crew division # 2 on the position of the F/A.

Position	**The RRJ-95 F/A**
Sex	Male
Age	21
Class	3
Education	Secondary

The RRJ-95 transition training	Over February 14 – February 17, 2018 at the Aeroflot Aviation School, PPEI under the RRJ-95 (SSJ-100) Aircraft Cabin Crewmembers Transition Training program
The civil aviation F/A license, validity	# 0070140, issued permanent on February 23, 2018 by the FATA Higher Qualification Commission department
Valid authorization as per the aircraft types	A-320 19.04.2018, B-737 13.06.2018, RRJ-95 12.11.2018
Advanced training	09.02.2018
The RRJ-95 check flight	02.10.2018, at the Aeroflot, PJSC Onboard Passenger Service Department Flight Safety Inspection, the good mark
Water emergency and rescue training	20.12.2017 at Aeroflot Aviation School, PPEI
Land emergency and rescue training	18.10.2018 at Aeroflot Aviation School, PPEI
Spring-summer period authorization	29.04.2019
Medical certificate	October 10, 2017, II class medical certificate BT # 036392, valid till October 10, 2022, issued by the Aeroflot, PJSC medical center MFEC
Total flying time	651 hrs 41 min
The RRJ-95 flying time	50 hrs 31 min
Flying time over the last month	Had not have flights
Flying time on the day of the accident	00 hrs 28 min
Preflight rest	More than 12 hrs at home
Total duty time on the day of the accident	02 hrs 20 min
Preflight medical check	At the Aeroflot, PJSC crew preflight medical check unit on 05.05.2019
Air accidents and incidents in the past	None

According to the employment contract # 303 of March 7, 2018 and the Aeroflot, PJSC customer service deputy general manager Order # 4318/л of March 27, 2018 he was employed at the Aeroflot, PJSC Onboard Passenger Service Department cabin crew division # 9 on the position of the F/A.

1.5.3. ATC personnel

The air traffic control at Sheremetyevo aerodrome had been ensured by the State ATM Corporation, FSUE Computer-Aided ATC Moscow Center branch Sheremetyevo ATC center (hereinafter referred to as the Center).

The air traffic control at the area of Sheremetyevo aerodrome had been ensured by the Moscow Air Hub ATC Center.

Position	**The Center air operations supervisor**
On the day of the accident acting as	The aerodrome air operations supervisor
Sex	Male
Age	55
Education	Higher: the Order of Lenin Academy for Civil Aviation
In-service time	Authorized to work as the air operations supervisor from 2016, the Computer-Aided ATC Moscow Center branch Order # 848 of July 15, 2016 by the FATA Airspace Management Department decision # 8 of July 8, 2016
The ATC officer license, number, date of issue, validity	СД # 010076, issued on February 11, 1998 by Federal Aviation Service, valid till August 26, 2020
Class	1st class of the ATC officer, assigned on January 10, 1991 by the Ministry of Civil Aviation Local Qualification Commission, the Minutes of Meeting # 2 of January 10, 1991
Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, Controllers-Instructors, the Simulator Controllers-Instructors, the ATM Personnel, Authorized to Work As the Air Operations Supervisor, Senior Controller, the Simulator Controller-Instructor)» in 2017, at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 022930). The advanced training under the program «The Aviation English language (to the ATM personnel)» in 2018 at the

	Air Navigation Institute, NSEI FPE, Moscow (license # 030903, certificate # 018865)
Theoretical knowledge check	15.07.2018
Practical skills check	20.08.2018
Medical certificate	Valid till January 15, 2020

Position	**The Center senior controller**
On the day of the accident acting as	the senior controller
Sex	Male
Age	48
Education	Higher: Saint-Petersburg State University for Civil Aviation, FSEI HPE in 2007
In-service time	Authorized to work as the air operations supervisor from 2014, the Computer-Aided ATC Moscow Center branch Order # 8 of January 15, 2014 by the Minutes of Meeting # 10 of the ATC officers certification commission to the FATA Higher Qualification Commission of December 26, 2013. Authorized to work as a senior controller from 2015, the Computer-Aided ATC Moscow Center branch Order # 360 of March 25, 2015 by the Minutes of Meeting # 4 of the FATA Central Regions Air Transport Interregional Territorial Department Territorial Qualification Commission of March 13, 2015
The ATC officer license, number, date of issue, validity	СД # 010037, issued by Federal Aviation Service on February 11, 1998, valid till August 26, 2020
Class	1st class of the ATC officer, assigned on December 8, 2000 by the Central Regions District Interregional Territorial Directorate Regional Qualification Commission, the Minutes of Meeting # 23 of December 8, 2000
Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, the Controllers-Instructors, the Simulator Controller-Instructors) » in 2017,

	at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 022587). The advanced training under the program «The Aviation English language (for the ATC personnel, authorized to air traffic support in the English Language)» in 2017 at the Air Navigation Institute, NSEI FPE, Moscow (license # 026797, certificate # 017194)
Theoretical knowledge check	14.04.2017
Practical skills check	As: – senior controller - on 18.03.2019; – air operations supervisor – on 10.07.2018; – controller-instructor – on 20.09.2018; – at the Tower C1 sector – on 06.04.2019
Medical certificate	Valid till September 20, 2019

Position	**The Center Tower controller**
On the day of the accident acting as	The Center Tower C1 sector controller
Period of time the aircraft had been under his control	14:56 - 15:03
Sex	Male
Age	48
Education	Secondary: Riga Higher Air Navigation College for Civil Aviation in 1991
In-service time	Authorized to work as the senior controller from 2016, the ATM Sheremetyevo Center Order # 4 of September 2, 2016 by the FATA Central Regions Air Transport Interregional Territorial Directorate decision # 14 of August 31, 2016
The ATC officer license, number, date of issue, validity	СД # 003939, issued by Federal Aviation Service on January 12, 1998, valid till April 29, 2020
Class	1^{st} class of the ATC officer, assigned by Federal Air Transport Service Higher Qualification Commission on November 21, 2001, the Minutes of Meeting # 21/У of November 21, 2001

Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, Controllers-Instructors, the Simulator Controllers-Instructors, the ATM Personnel, Authorized to Work As the Air Operations Supervisor, Senior Controller, the Simulator Controller-Instructor)» in 2018, at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 030978). The advanced training under the program «The Aviation English language (to the ATM personnel)» in 2017 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 031087), having been subject to testing in 2019 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 020986)
Theoretical knowledge check	19.04.2017
Practical skills check	Acting as: – senior controller - on 10.07.2018; – at the Tower C1 sector – on 29.03.2017
Medical certificate	Valid till March 30, 2020

Position	**The Center Tower controller**
On the day of the accident acting as	The controller at the Center Tower C2 sector
Period of time the aircraft had been under his control	15:27 - 15:29
Sex	Male
Age	29
Education	Higher: the State Flight Academy of Ukraine in 2011
In-service time	Authorized to work as the Tower sector C1, C2, C1C2 sector controller from 2018, the Computer-Aided ATC Moscow Center branch Order # 124 of October 25, 2018
ATC officer license, number, date of issue, validity	СД # 000871, issued by FATA on June 25, 2014, valid till October 19, 2019

Class	1st class of the ATC officer, assigned on March 29, 2016 by the FATA Airspace Management Department commission, the Minutes of Meeting # 4 of Mach 29, 2016
Advanced training	The advanced training under the program «The Air Traffic Management (to the ATC officers) » in 2018 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 033946). The advanced training under the program «The Aviation English language (for the ATC personnel, authorized to the air operations support in the English Language) » in 2016 at the Air Navigation Institute, NSEI FPE southern branch, Rostov-on-Don (license # 015632).
Theoretical knowledge check	13.11.2018
Practical skills check	13.10.2018
Medical certificate	Valid till April 11, 2020

Position	**Moscow Air Hub ATC Center air operations supervisor**
On the day of the accident acting as	Moscow Air Hub ATC Center air operations supervisor
Sex	Male
Age	40
Education	Higher: Riga Air Navigation Institute in 2002
In-service time	Authorized to work as the Moscow Air Hub ATC center air operations supervisor from 2013, the Computer-Aided ATC Moscow Center branch Order # 416 of June 4, 2013, the FATA Higher Qualification Commission on the ATM and Aerospace SAR personnel certification subcomission Minutes of Meeting # 5 of May 23, 2013
ATC officer license, number, date of issue, validity	СД # 010284, issued by Federal Aviation Service on February 12, 2002, valid till June 26, 2020
Class	1st class of the ATC officer, assigned on February 14, 2008 by the FATA Higher Qualification Commission, the Minutes of Meeting # 2 of February 14, 2008

Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, Controllers-Instructors, the Simulator Controllers-Instructors, the ATM Personnel, Authorized to Work As the Air Operations Supervisor, Senior Controller, the Simulator Controller-Instructor)» in 2017, at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 020872). The advanced training under the program «The Aviation English Language (the R/T phraseology to the ATM personnel) in 2016 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 017073)
Theoretical knowledge check	30.03.2017
Practical skills check	28.02.2019
Medical certificate	Valid till May 25, 2019

Position	**Moscow Air Hub ATC center senior controller**
On the day of the accident acting as	Moscow Air Hub ATC center senior controller
Sex	Male
Age	32
Education	Higher: Ulyanovsk Higher College for Civil Aviation (institute) in 2008
In-service time	Authorized to work as the Moscow Air Hub ATC center senior controller from 2017, the Computer-Aided ATC Moscow Center branch Order # 95 of January 30, 2017, the FATA Central Interregional Territorial Directorate decision # 2 of January 20, 2017
ATC officer license, number, date of issue, validity	СД # 002047, issued by Federal Aviation Service on July 8, 2008, valid till May 30, 2019
Class	1st class of the ATC officer, assigned on June 26, 2015 by the FATA Airspace Management Department decision # 1 of June 26, 2015
Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, Controllers-Instructors,

	the Simulator Controllers-Instructors, the ATM Personnel, Authorized to Work As the Air Operations Supervisor, Senior Controller, the Simulator Controller-Instructor)» in 2017 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 024677). The advanced training under the program «The Aviation English Language (to the ATM personnel) » in 2018 at the Air Navigation Institute, NSEI FPE, Moscow (license # 031082, certificate # 018937).
Theoretical knowledge check	15.02.2019
Practical skills check	12.11.2018
Medical certificate	Valid till 25.03.2020

Position	**the Moscow Air Hub ATC center radar control and procedural control officer**
On the day of the accident	Carried out the ATM at the radar control officer duty station at the Moscow Air Hub ATC center radar control unit Sheremetyevo Radar + Sheremetyevo Approach combined sector
The period of time the aircraft had been under his control	15:03 - 15:07 and 15:12 - 15:27
Sex	Male
Age	30
Education	Higher: Moscow State Technical University for Civil Aviation, FSFEI HPE in 2012
In-service time	Authorized to work as the radar control and procedural monitoring officer from 2013
ATC officer license, number, date of issue, validity	СД # 018592, issued on March 10, 2013 by FATA, valid till April 9, 2021
Class	2nd class of the ATC officer, assigned on May 18, 2016 by the FATA Central Regions Air Transport Interregional Territorial Directorate decision, the Minutes of Meeting # 8 of May 18, 2016

Advanced training	The advanced training under the program «The Air Traffic Management (to the ATC officers)» in 2018 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 028957) The advanced training under the program «The Aviation English Language (to the ATM personnel)» in 2018 at the Air Navigation Institute, NSEI FPE, Moscow (license # 029137, certificate # 018227)
Theoretical knowledge check	13.02.2018
Practical skills check	06.01.2019
Medical certificate	Valid till July 6, 2020

Position	**the Moscow Air Hub ATC center radar control and procedural control officer**
On the day of the accident	Carried out the ATM at the procedural control officer duty station at the Moscow Air Hub ATC center Sheremetyevo Radar + Sheremetyevo Approach combined sector
The period of time the aircraft had been under his control	15:03 - 15:07 and 15:12 - 15:27
Sex	Male
Age	41
Education	Secondary: Krasnoyarsk Aviation Technical College for Civil Aviation in 2003
In-service time	Authorized to work as the radar control and procedural control officer from 2004
ATC officer license, number, date of issue, validity	СД # 018916, issued on by Federal Aviation Service on June 9, 2004, valid till April 6, 2022
Class	1st class of the ATC officer, assigned on June 23, 2014 by the FATA HQC, the Minutes of Meeting # 6 of June 23, 2014
Advanced training	The advanced training under the program «Air Traffic Management (to Senior Controllers, Controllers-Instructors, the Simulator Controllers-Instructors, the ATM Personnel, Authorized to Work As the Air Operations Supervisor,

	Senior Controller, Controller-Instructor, the Simulator Controller-Instructor)» in 2017 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 020905) The advanced training program «The Aviation English Language (the R/T phraseology to the ATM personnel)» in 2018 at the Air Navigation Institute, NSEI FPE, Moscow (license # 033989
Theoretical knowledge check	30.03.2017
Practical skills check	06.01.2019
Medical certificate	Valid till November 19, 2019

Position	**the Moscow Air Hub ATC center radar control and procedural control officer**
On the day of the accident	Carried out the ATM at the radar control officer duty station at the Moscow Air Hub ATC center approach control unit M2 sector
Period of time the aircraft had been under his control	15:07 - 15:12
Sex	Male
Age	24
Education	Higher: Moscow State Technical University for Civil Aviation, FSFEI HPE in 2012
In-service time	Authorized to work as the radar control and procedural control officer from 2017
ATC officer license, number, date of issue, validity	СД # 004670, issued by FATA on January 18, 2017, valid till January 18, 2020
Class	3rd class of the ATC officer, assigned on January 18, 2017 by the decision of the FATA Central Interregional Territorial Directorate of January 18, 2017, the Minutes of Meeting # 1
Advanced training	The advanced training under the program «The Air Traffic Management (to the ATC officers)» in 2019 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 034838)

	The advanced training under the program «The Aviation English Language (to the ATM personnel)» in 2019 at the Air Navigation Institute, NSEI FPE, Moscow (license # 035041, certificate # 020908)
Theoretical knowledge check	25.01.2019
Practical skills check	08.10.2018
Medical certificate	Valid till February 11, 2020

Position	**Moscow Air Hub ATC center radar control and procedural control officer**
On the day of the accident	Carried out the ATM at the procedural control officer duty station at the Moscow Air Hub ATC center approach control unit M2 sector
Period of time the aircraft had been under his control	15:07 - 15:12
Sex	Male
Age	36
Education	Secondary: Saint-Petersburg State University for Civil Aviation, FSEI HPE in 2011
In-service time	Authorized to work as the radar control and procedural control officer from 2012
ATC officer license, number, date of issue, validity	СД # 001824, issued by FATA on March 15, 2012, valid till July 4, 2020
Class	2nd class of the ATC officer, assigned on October 18, 2017 by the FATA Central Interregional Territorial Directorate, decision # 20 of October 18, 2017
Advanced training	The advanced training under the program «The Air Traffic Management (to the ATC officers)» in 2016 at the Air Navigation Institute, NSEI FPE, Moscow (certificate # 017275) The advanced training under the program «The Aviation English language (the R/T phraseology to the ATM personnel, authorized to the air operations support in the English language» in 2016 at the Air Navigation Institute,

	NSEI FPE, Moscow (license # 017621, certificate # 017097)
Theoretical knowledge check	18.05.2018
Practical skills check	26.06.2018
Medical certificate	Valid till February 19, 2020

1.6. Aircraft information

Fig. 26. The RRJ-95B RA-89098 airplane before the air accident

Aircraft type	The RRJ-95 airplane (the RRJ-95B model)
Manufacturer	SCAC, JSC
Date of manufacture	August 17, 2017
MSN	95135
Nationality and registration marks	RA-89098
State registration certificate	# 8245 of 14.09.2017, issued by FATA Flight Safety Inspection
Proprietor	Veb-Leasing, JSC, leased out to Aeroflot, PJSC (the leasing certificate of September 18, 2017)

Airworthiness certificate	# 2021170075 of September 27, 2017, issued by FATA with the validity up to September 27, 2019
Aircraft design service life and life limit	70000 FH, 54000 flights, 25 years
Design service life and life limit current phase	15000 FH, 10000 flights, 15 years
TSN	2710 hrs, 1658 flights
The remaining design life and life limit as per the current phase	12290 FH, 8342 flights
TBO	Not determined by the manufacturer, had been operated on condition
Last overhaul	None
Last scheduled maintenance	On April 5, 2019 the preflight check had been carried out on the airplane, including these in the amount of the A-check (A01 package) + 375 FH scheduled maintenance forms (work card # 148/1, H01154794 of April 5, 2019)
Last line maintenance	On May 5, 2019 at the departure from Sheremetyevo airport the Aeroflot, PJSC employees had carried out the T + DY form line maintenance works (work card # 212/6 of May 5, 2019)

The engines, manufactured by POWERJET S.A. (France) and APU, manufactured by HONEYWELL (USA) had been mounted on the airplane.

Engines	Powerplant # 1 (left)	Powerplant # 2 (right)	APU
Type	SaM-146-1S-17	SaM-146-1S-17	RE220[RJ]
MSN	146377	146397	P-1127
Date of manufacture	31.05.2017	31.07.2017	23.16.2016
Service lives and life limits	Not assigned, the operation on condition	Not assigned, the operation on condition	Not assigned, the operation on condition
TSN, hrs/cycles	1886/1155	1829/1161	2039/3055

Number of overhauls	None	1 (local repair)	None
Date and location of the last overhaul	-	07.06.2018, the Saturn Scientific Plant (Rybinsk)	-
TBO, hrs/cycles	-	154/112	-

The aircraft maintenance

According to the maintenance organization certificate # 285-16-148 of October 24, 2016, issued by FATA, Aeroflot, PJSC is entitled to carry out the RRJ-95 aircraft line and scheduled maintenance.

The Aeroflot, PJSC MOE is approved by the FATA Civil Aircraft Continuing Airworthiness Department on February 12, 2016, the Bermuda Department of Civil Aviation in the European region on June 1, 2016 and approved by the Aeroflot, PJSC general manager on August 9, 2016.

In the progress of the aircraft operation all the line and scheduled maintenance works to the RRJ-95B RA-89098 aircraft had been carried out by the Aeroflot, PJSC personnel.

The maintenance of the aircraft had been carried out, compliant to the Aeroflot – Russian Airlines, PJSC RRJ-95B aircraft MP (edition 14) (hereinafter referred to as the MP), approved by the FATA Civil Aircraft Continuing Airworthiness Department on November 26, 2018.

Scheduled maintenance

As per the MP item 2-3-2-5, the A-Check (the A01 and A02 packages) maintenance form consists of the MP tasks with the schedule of 750 flight hours (FH) and/or 100 calendar days (DY), as well as 1500 FH and/or 200 DY.

Line maintenance

As per the MP item 2-3-2-1 the transit maintenance («TRANSIT» «T») constitutes a complex of works that shall be carried out at every return to the base airport. All the MP tasks, being a part of this form, are designated with the respective note in the description of the MP Section 3 task (Section 3 incorporates the MP tasks to the system modules, powerplant, the inspection of the structure, the area inspections and airworthiness limitations).

According to the MP item 2-3-2-2, the daily maintenance ("DAILY" "DY"), in a typical case, shall be performed at least once a day to the aircraft that is serviceable/efficient and operated on a regular basis. When required (for example, to return the aircraft to the base airport), it is allowed to perform the next daily maintenance form no later than 48 hours from the date and time of the previous performance.

The aircraft scheduled maintenance in the amount of A01 + 375 FH and A02 packages works had been carried out as such:

– on April 5, 2019, the work card # 148/1, H0154794, at the TSN of 2556 hrs, 1546 cycles. The performance of the A01 + 375 FH works had been combined with the works on the aircraft preflight check after its parking (from December 30, 2018 to March 24, 2019) due to the absence of the engine and the preparation for the flights through the spring-summer period. On March 24, 2019 the SaM 146-1S-17 # 146397 (right) engine had been mounted to the airplane;

– on April 11, 2019, the work card # 034/1, H0184546, at the TSN of 2580 hrs, 1563 cycles.

Into the works as per the A01 + 375 FH form 75 additional works had been carried out, including the evaluation of the condition of the right wing fuel filling access door. On the results of the evaluation of the condition of the right wing fuel filling access door (the work card # 15826434, sequence # 156) the deformation of the fuel filling access door attachment fittings had been corrected; the access door opening fitting in had been checked; the closing of the access door latches in a closed position had been checked as well.

Into the works as per the A02 3 additional works had been carried out, including the evaluation of the condition of the right wing fuel filling access door (the work card # 16161931, the sequence # 111). The work had been carried out due to the detection of the open position of the access door and the malfunction of one latch, at that the latch aligning had been carried out and the correctness of the access door seating had been checked.

The appendices to the work cards as per the A01 and A02 forms read the stamps of the completion of the works, provided for by the MP, and the monitoring of their performance.

Prior to the last flight of May 5, 2019 the T + DY form works had been carried out to the airplane (work card # 212/6). There had been no comments by the crew on the aircraft systems functioning through the previous flight.

At the aircraft inspection on the accident site it had been determined that the parking plugs and covers, had been removed at the aircraft preflight check. The full set of the safety «pins» had been revealed at the assigned location in the cockpit.

Prior to the departure of May 5, 2019 from Sheremetyevo airport the aircraft had been refueled with the TS-1 jet fuel in the amount of 4438 kg at the remaining fuel of 3000 kg (the total fueling of 7438 kg).

Into the investigation activities the fuel samples had been taken out of the inner and middle sections of the right fuel tank, as well as out of the spots # 1 and 2 of the inner section of the right fuel tank. The fuel samples had been transferred for examination (see Section 1.16.1.16.1 of the Report).

Into the parking period of the aircraft (on January 6 and March 12, 2019) the removal (transposition) of the EIU-100 units (work cards # 15840297 (sequence # 182) and # 16050060 (sequence # 208)) had been carried out due to the necessity to restore airworthiness of the RRJ-95B RA-89111 and RA-89105 aircraft. Among the works that should have been performed before the transposition it had been required to make sure that there had been no events of the lightning strike. There had been no comments stated.

At the point of the air accident the EIU-100 units # 575084010 and # 3640820134 had been installed aboard the RA-89098 aircraft. Both units had been installed on March 28, 2019.

Through the operation of the aircraft there is 1 entry introduced of January 25, 2018 on the cabin doors, the malfunction of the lifting, locking and latching mechanism, namely: *«…the 1L door is closed with difficulty, creaks»*. As for this comment the works had been carried out, compliant to AMM 52-10-00-010-801 (the automated opening of the entry (service) door with the deployment of the escape slide) and 52-71-00-710-801 edition 02 revision 02 (the monitoring of the entry (service) door gas springs. There had been no comments stated.

As from April 15, 2019 the flights had been performed with one defect, deferred up to May 5, 2019: the removed access door to the refueling connector (622CB). The unrestricted performance of flights with this malfunction is provided for by MCDL 0828, page 3 D-15 (the DD category). As to the RA-89098 aircraft the comments on the filler neck access door as from January 4, 2018 had been introduced 11 times. This malfunction had not anyhow affected the outcome of the flight, still the multiple recurrence of the defect indicates certain difficulties through the technical operation of this aircraft type (see Section 1.18.29 of the Report as well).

Through the operation of the aircraft there had been no malfunction detected, attributed to the flight control system or the aircraft lightning or static electricity encounter. Among the structural damage, having been identified before the air accident, there had been no damage, typical of the aircraft strike by lightning or static electricity.

There had been the visible damage to the skin as follows:

– the powerplant # 1 air intake lip; the damage had been subject to permanent repair on March 30, 2017;

– the delamination of the protective coating of the engine 1 channel air intake panel between 6 and 8 hours at the area of the lip riveted seam. On November 20, 2017 the restoration works had been performed;

– the disruption of the paint coating to the 1R door decompression access door. The paint coating restored on September 15, 2018;

– the disruption of the paint coating on the slats front upper area with no damage to the base layer. The paint coating restored on November 6, 2018;

– the cracking of paint coating on the panel 713. The paint coating restored on April 8. 2019.

The listed damage does not match this, typical of the exposure to the lightning, having been identified in the progress of the investigation on the right front fuselage (see Section 1.3 of the Report).

1.7. Meteorological information

On May 5, 2019 the weather conditions in the European territory of the Russian Federation and at Moscow aerodromes were determined by the effect of the Mediterranean cyclone trough front part, the center of which was located over the central part of Italy and was outlined by the 995th isobar, the pressure in the center was 994.3 hPa. A cyclone (a stationary high baric formation) was observed throughout the entire strata of the atmosphere. The cyclone trough at the ground surface spread from the southwest to the northeast. According to the weather map of 12:00, its axis passed west of Lvov through Minsk and Velikiye Luki, where a cold front with waves was located. The Moscow air zone was affected by the warm sector of the cyclone and the occlusion front, which had moved from southwest to the northeast at the speed of 40–60 km/h and determined the weather of the Moscow aerodromes.

The occlusion front had caused the growth of the cumulonimbus clouds with the ceiling of 8 – 10 km, the thunderstorm activity with the increase of the surface wind of the southwestern direction up to 15 – 19 m/s, the shower rain precipitation, occasionally degrading the visibility down to 1500 – 2000 m. At Sheremetyevo aerodrome from 13:38 to 13:49 the thunderstorm, the shower rain with the visibility degrade down to 1700 m and the increased southwestern wind up to 15 m/s had been observed. At Vnukovo aerodrome from 14:18 to 14:35 the thunderstorm with the light rain had been observed, the visibility of 5 – 7 km, at the thunderstorm the southwestern wind increased up to 15 m/s. At Domodedovo aerodrome from 15:01 to 15:13 the thunderstorm with the light rain had been observed, the visibility of 10 km and the southwestern wind increase at the thunderstorm up to 19 m/s.

At 09:54 the duty forecaster, in view of the forecast and actually observed surface gusting wind of the velocity of 11 – 14 m/s, issued warning 1 on the windshear at Sheremetyevo aerodrome, valid over 10:00 - 14:00 of May 5, 2019 - the windshear at the approach is forecast:

UUEE WS WRNG 1 050954 VALID 051000/051400 WS IN APCH FCST.

On May 5, 2019 the aircraft flight crews via ATC authorities relayed the inflight weather to the observation point meteorologist: at Sheremetyevo aerodrome at 10:33 the moderate windshear, moderate turbulence (AFL 2107), at 13:41 – the strong windshear (AFL 261).

At 13:47 the warning 2 had been issued on the windshear at the Sheremetyevo aerodrome, valid over 14:00 - 18:00 on May 5, 2019: the windshear at the approach is forecast:

UUEE WS WRNG 2 051347 VALID 051400/051800 WS IN APCH FCST.

At the daily flight plan of May 5, 2019 the SU-1492 flight en route from Moscow (Sheremetyevo) to Murmansk had been scheduled for 14:50.

As a part of the preflight preparation at the briefing the crew had been given the flight documentation with the meteorological data out of the Roshydromet Head Aeronautical Meteorological Center, FSFI preflight data automated complex, consisting of the TAF forecasts form for the departure aerodrome, aerodrome of the intended landing and the alternate one: this, valid through 12:00 of May 5, 2019 - 12:00 of May 6, 2019 for Murmansk, Pulkovo, Naryan-Mar, Syktyvkar, Nizhny Novgorod aerodromes, through 12:00 of May 5, 2019 - 21:00 of May 5, 2019 for Arkhangelsk and through 12:00 of May 5, 2019 - 18:00 of May 6, 2019 for Domodedovo aerodrome, the actual weather in a METAR code of 13:00 for Murmansk, Arkhangelsk, Pulkovo, Naryan-Mar, Syktyvkar, Nizhny Novgorod, Domodedovo and in a SPECI code as of 13:01 for Sheremetyevo aerodrome, the SIGMET 1 advisory over the Moscow FIR, valid within 12:30 - 16:30; the significant weather charts through FL 100 – 450 by London World Area Forecast Center for the European region, valid as of 12:00 and 18:00 of May 5, 2019. The weather documentation package integrated the chart of the wind velocity and direction - Route chart WX: 05MAY 16:06 UTC FL352.

The crew had been held another meteorological consultation at the briefing at 13:39, at which had been given the new TAF forecasts form, valid over 12:00 of May 5, 2019 - 12:00 of May 6, 2019 for Murmansk, Pulkovo, Naryan-Mar, Syktyvkar, Nizhny Novgorod, Sheremetyevo aerodromes, over 12:00 of May 5, 2019 - 21:00 of May 5, 2019 for Arkhangelsk and over 12:00 of May 5, 2019 - 18:00 of May 6, 2019 for Domodedovo aerodrome and the updated data of the actual weather in a METAR code as of 13:30 for Murmansk, Arkhangelsk, Pulkovo, Naryan-Mar, Syktyvkar, Nizhny Novgorod, Domodedovo aerodromes, in a SPECI code for Sheremetyevo aerodrome of 13:38 and the SIGMET 1 advisory over the Moscow FIR, valid through 12:30 - 16:30.

The aerodrome forecast for the Moscow (Sheremetyevo) departure aerodrome in a TAF code had been issued at 10:59 on May 5, 2019, valid through 12:00 of May 5, 2019 - 12:00 of May 6, 2019:

TAF UUEE 051059Z 0512/0612 18008G15MPS 9999 BKN030 TX23/0612Z TN06/0602Z

TEMPO 0512/0518 -TSRA BKN015CB BECMG 0518/0519 18003MPS SCT030=.

Surface wind 180° – 08 m/s, gust 15 m/s, visibility of more than 10 km, broken cloud, the cloud base at 900 m, maximum temperature + 23 °C at 12:00 on May 6, 2019, minimum temperature + 06 °C at 02:00 on May 6, 2019, occasionally from 12:00 till 18:00 on May 5, 2019 thunderstorm, light shower rain, broken cumulonimbus cloud, the cloud base at 450 m, gradually from 18:00 to 19:00 on May 5, 2019 surface wind 180°–03 m/s, scattered cloud, the cloud base at 900 m.

The actual weather at the Moscow (Sheremetyevo) departure aerodrome in a SPECI code as of 13:38 on May 5, 2019:

SPECI UUEE 051338Z 24008G15MPS 7000 -TSRA BKN053CB 15/13 Q1013 R24L/290045 R24C/290045 NOSIG=.

Surface wind 240°–08 m/s, gusts 15 m/s, visibility 7000 m, thunderstorm, light shower rain, broken cumulonimbus cloud, cloud base at 1590 m, air temperature + 15 °C, dew point + 13 °C, the QNH atmospheric pressure 1013 hPa, the RWY 24L condition: wet, friction coefficient 0.45, the RWY 24C condition: wet, friction coefficient 0.45, no significant changes.

The SIGMET 1 advisory over the Moscow FIR on May 5, 2019, valid over 12:30 - 16:30:

UUWV SIGMET 1 VALID 051230/051630 UUWV-

UUWV MOSCOW FIR EMBD TS FCST S OF N57 TOP FL360 MOV N 30KMH INTSF=.

The SIGMET 1 advisory, issued by the Moscow UUWV- meteorological watch office to the MOSCOW FIR (UUWV-), valid from 12:30 on May 5, 2019 till 16:30 on May 5, 2019 the embedded thunderstorm is forecast to the south off 57° N of the vertical extension up to FL 360, is moving to the north with the velocity of 30 km/h, it is intensifying.

At 14:35 the crew of the SU-1492 flight aircraft acknowledged to the Delivery ATC officer the ATIS BRAVO information, having been monitored, that integrated the data out of the local weather report as of 14:30: surface wind 140°– 03 m/s, gusts 06 m/s, visibility more than 10 km, few cumulonimbus cloud at 1800 m, air temperature 17 °C, dew point 13 °C, QFE 742 mm of mercury / 989 hPa, QNH 1011 hPa, no significant changes.

At 15:03 the RRJ-95B RA-89098 airplane took off from Sheremetyevo aerodrome.

At about 15:08:10 at the altitude of 8900 ft (2700 m) QNE it had been the onset of the emergency. According to the flight crew the aircraft encountered the lightning strike. As per the Vnukovo TDWR data as of 15:00, 15:10 on May 5, 2019 to the west, at 30 – 40 off Sheremetyevo airport, at the area of the Istra water reservoir, the cumulonimbus cloud had been observed with the ceiling at 8 – 9 km, related to the occlusion front, the thunderstorm, its direction of movement had been to northeast (the azimuth of 41°– 42°), the velocity of movement had been ≈ 15 m/s.

As per the data of radiosonde observation by the Moscow (Dolgoprudny) upper-air station as of 12:00 on May 5, 2019 the wind parameters (the direction, the velocity) features were subject to analysis through the layer from ground level to technical atmosphere of 700 hPa (the latitude of

2848 m). Within a layer from 390 m to 211 m (from 1280 ft. till 692 ft.) the wind velocity had been varying between 10 m/s and 5 m/s that implies the presence of windshear into this layer.

At 15:31 via the main observation station office phone the Alarm signal had been received from the Sheremetyevo International Airport, JSC Operations Center Directorate shift supervisor. The observation station meteorologist had generated the weather report out of the AMIS-RF aerodrome meteorological data measurement system and immediately relayed the information to the Topaz ATC automated complex, the Popugay voice message automatic generator, the Moscow-Reserve backup complex, the Syntez-AR4 ATC automated complex and to the meteodisplays.

The actual weather at Moscow (Sheremetyevo) aerodrome, having been issued at the Alarm signal, drawn up in a special local weather report of 15:31: surface wind 160º– 7 m/s, gusts 10 m/s, RVR at touchdown 10 km, at the RWY midpoint 10 km, at the RWY stop end 10 km, scattered cumulonimbus cloud, the cloud base at 1800 m, air temperature + 17 °C, dew point + 11 °C, QNH atmospheric pressure 1012 hPa, QFE 742 mm of mercury / 990 hPa, the RWY 24L condition: wet, friction coefficient 0.45, landing forecast: no significant changes.

1.8. Aids to navigation

At the point of the air accident the following radio navaids had been operating at the aerodrome: the SP-90 ILS, the TERMA SCANTER 2001 airfield surveillance radar and the Ladoga data transmission system.

The SP-90 ILS at the RWY 24L out of the SP-90 localizer, the SP-90 glideslope, the outer and inner marker beacons (the RMM-95 system), the Parsec automated NDB out of locator at the outer marker and locator at the inner marker landing equipment had been operating normally, having been remotely monitored and controlled, there had been no failure or degrade signals recorded, the flight crews had not relayed any complaints concerning the system operation neither before, nor after the air accident, the equipment in question had not switched to the standby power supply. The system ensured the ICAO CAT II ILS approach.

As per the data recording means, the radio navaids had functioned as assigned. The ATC personnel had not stated any comments as to them.

1.9. Communications

At the Moscow (Sheremetyevo) aerodrome the aeronautical mobile communication to contact the aircraft flight crews, the VHF radio communication to transmit the meteorological data, the emergency back-up communication to contact the aircraft in distress, as well as the ground-to-ground communication of the air operations supervisor with the ATM facilities, supporting services, radio facilities operators, the alternate aerodromes are enabled.

The mobile and fixed radio communication aids at the Moscow (Sheremetyevo) aerodrome had operated as assigned. The Megaphone voice communication system ensured the control of the main and standby radio stations and loudspeaker communications. There had been complaints stated neither by the ATC personnel nor by the aircraft flight crews.

The RRJ-95B RA-89098 aircraft had been equipped with three Thales VDR.

From the point of the engines startup and in the progress of the flight – up to 15:08 – the crew proceeded the radio contact with the ATM facilities on the main frequency with the use of VDR 1. As the outcome of the aircraft exposure to the atmospheric electricity the operation of the VDR 1 had been disrupted (see Section 1.16.7 of the Report).

As from 15:09 the two-way radio communication had been restored on the emergency frequency of 121.5 MHz with the use of the VDR 2. Further on the radio contact with the ATM facilities had been proceeded on this frequency (see Section 1.18.26 of the Report for details).

1.10. Aerodrome information

The Moscow (Sheremetyevo) aerodrome belongs to A class aerodromes, being a part of the 1st class airport and civil aerodrome. By departmental affiliation it is subordinate to the Ministry of Transport of the Russian Federation. It is located 28 km northwest off the city of Moscow. The ARP reference position is 55º58′20.63″ N, 37º24′46.99″ E; the ARP altitude ASL is 190.1 m. The elevation (the aerodrome altitude) is + 192 m. The geodetic altitude as per the ПЗ-90.02 geodetic datum system is + 206.3 m. The magnetic variation is equal to + 11°. The time zone number is 2 (local time = UTC + 3 hrs).

The reference system in use is ПЗ-90.02. The type of the approved air operations − VFR/IFR.

The State Registration Certificate # 84, issued by FATA on December 30, 2015.

The Certificate of Conformity # АД 00033, issued by FATA on December 30, 2015, valid till December 30, 2020.

The aerodrome is qualified for international air operations and approved for the H24 operation under the established minima.

The indicator (index) of the aerodrome location: Moscow (Sheremetyevo) – УУЕЕ/UUEE (in the Russian Federation/in ICAO), the IATA code – ШРМ/SVO.

The Sheremetyevo International Airport, JSC general manager is a senior aviation chief of the Moscow (Sheremetyevo) aerodrome (the FATA Order # 65/1 of February 24, 2012).

The aerodrome is out of two rectangular airfields with the 4500 x 1830 m and 3800 x 500 m dimensions, interconnected with each other by the TWY-D. The aerodrome surface is a flat country, the soil is a silty loam with the grass cover, unsuitable for the aircraft landing.

The aerodrome integrates three artificial parallel RWYs (Fig. 27): the RWY 06C/24C (RWY-1) of an A class, the RWY 06R/24L (the RWY-2) of an A class and RWY06L/24R (the RWY-3) of an A class. The distance between the centerlines of the RWY-1 and RWY-2 amounts to 280 m, between the RWY-1 and RWY-3 is of 2130 m. The RWY-1 and RWY-2 centers are not shifted against each other. The RWY-1 and RWY-3 are misaligned against each other for 3375 m. The RWY-3 is closed for operation (the first NOTAM A1976/18 of April 26, 2018, the latest NOTAM A0930/19 of February 26, 2019).

The RWY 24L/06R is of the 3700 x 60 m dimensions, magnetic track angle = 244° (true track angle = 255°06′), magnetic track angle = 064° (true track angle = 075°04′). The PCN 64/R/A/W/T, the runway surface of the reinforced concrete (with the upper layer of 30 cm), the cement concrete (the lower layer of 25 cm). The threshold 24 reference position: 55°58′32.53″ N, 37°26′37.69″ E; the threshold 24 elevation – + 189.34 m. The RWY equipment ensures:

- with magnetic landing heading = 064° - the CAT I, II, IIIA precision approach;
- with magnetic landing heading = 244° - the CAT I, II precision approach.

The RWY cleared and graded areas extend for 90 m to both sides off the RWY-1 and RWY-2 axes. The ground surface of the RWY cleared and graded area at the points, adjacent to the artificial surfaces is on one level with them.

The air operations Instruction at the area of the Moscow (Sheremetyevo) is approved by the Sheremetyevo International Airport, JSC general manager on September 28, 2015 and registered at the FATA Central Interregional Territorial Directorate under the number ЦИ1-419 on September 1, 2015.

Fig. 28 presents the Sheremetyevo standard instrument departure[47] SID KN 24E chart. Fig. 29 presents the Sheremetyevo aerodrome ICAO ILS Y LOC Y RWY-24L approach chart.

[47] Hereinafter the presented charts are these, effective on the day of the air accident.

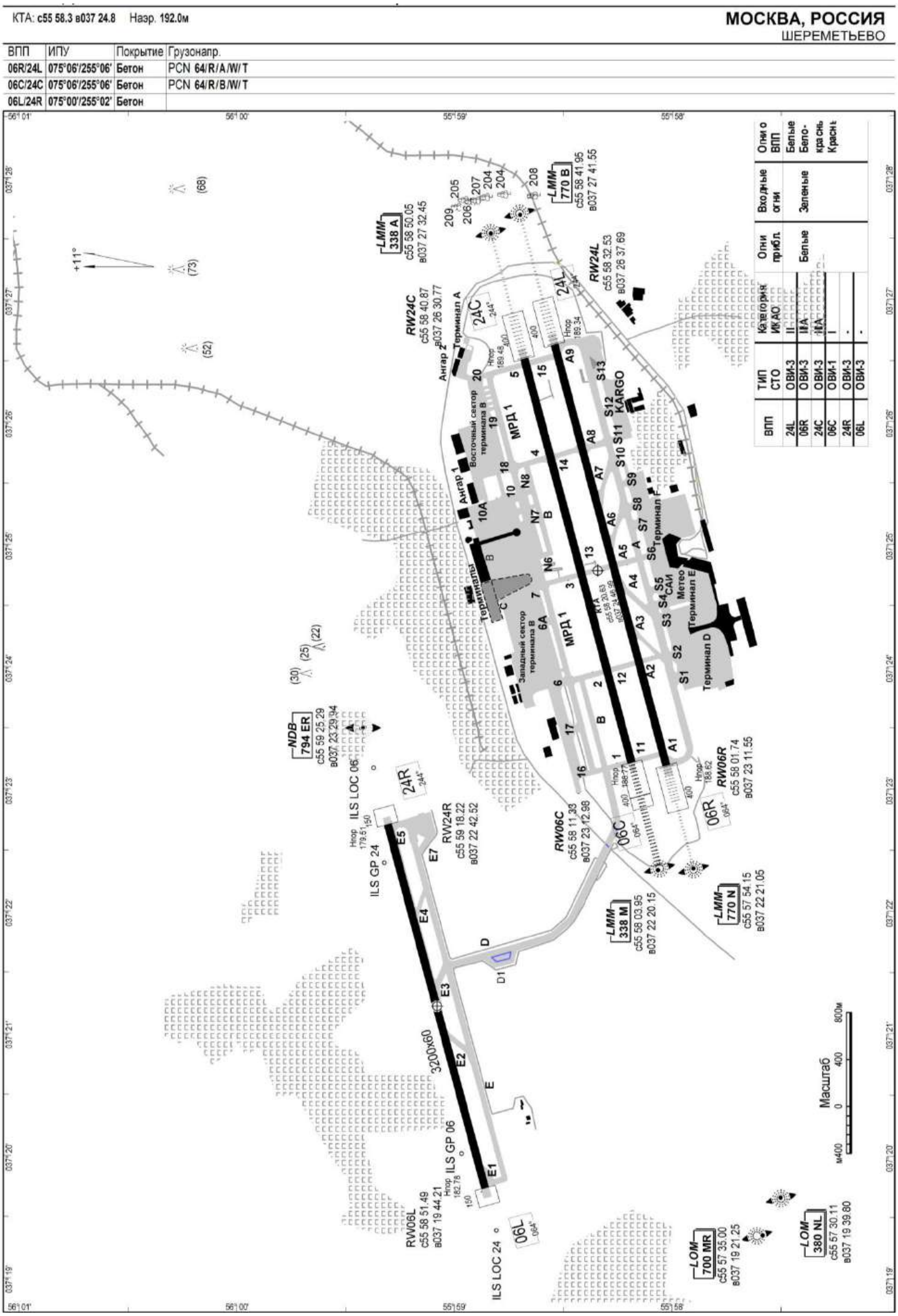


Fig. 27. The Moscow (Sheremetyevo) aerodrome chart

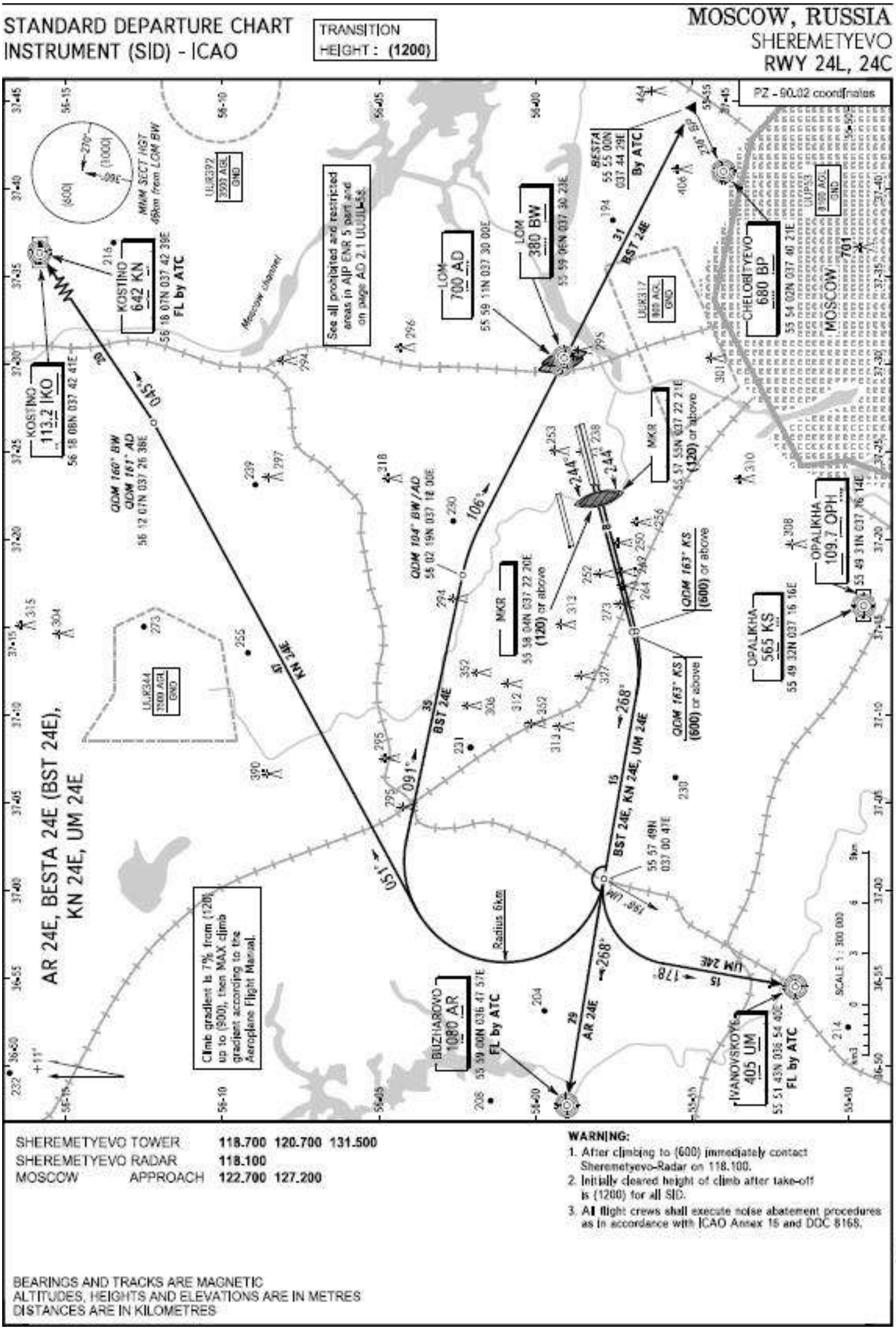
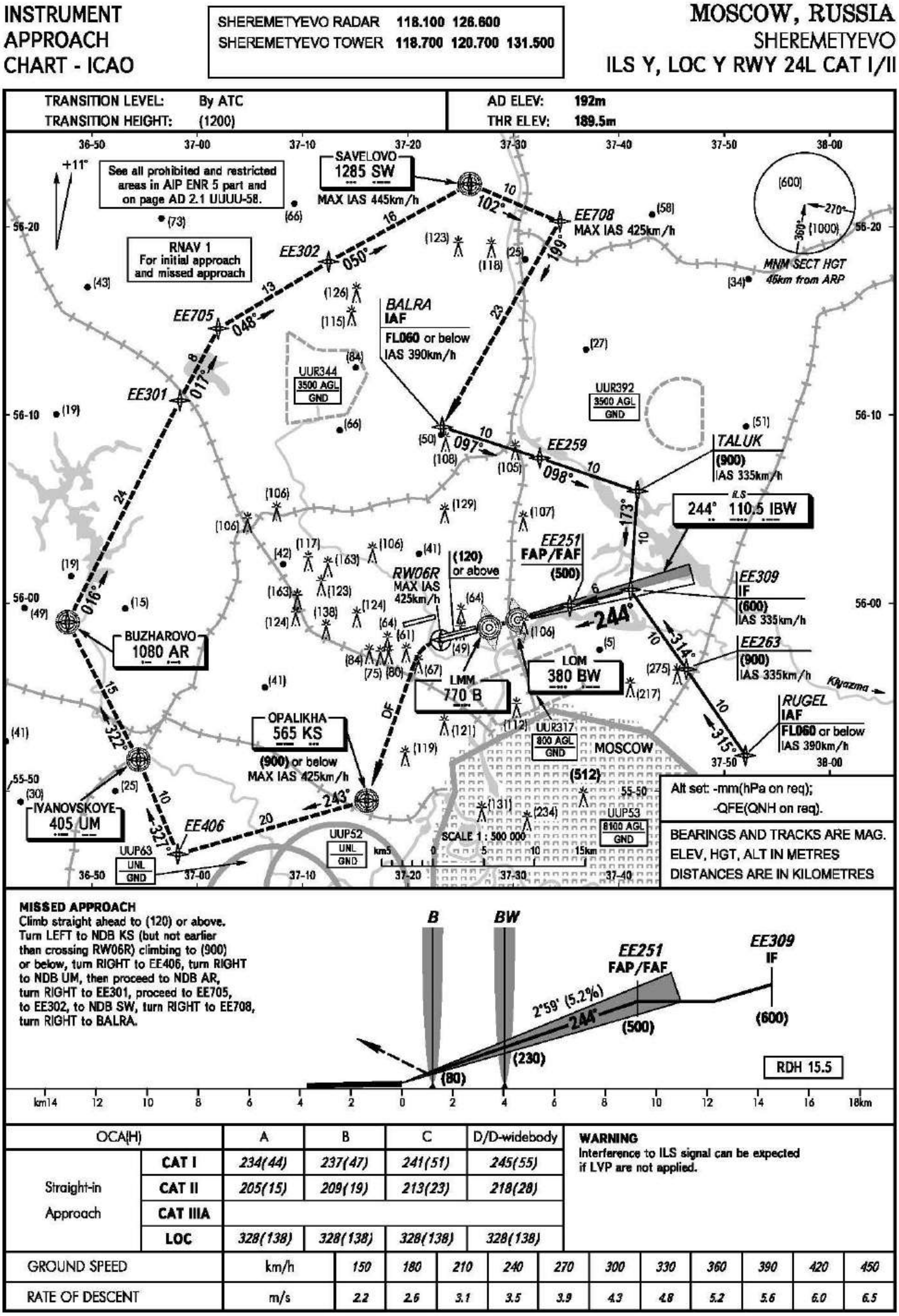


Fig. 28. The SID KN 24E standard departure chart out of the Sheremetyevo aerodrome area



OCA(H)		A	B	C	D/D-widebody
Straight-in Approach	CAT I	234(44)	237(47)	241(51)	245(55)
	CAT II	205(15)	209(19)	213(23)	218(28)
	CAT IIIA				
	LOC	328(138)	328(138)	328(138)	328(138)

GROUND SPEED	km/h	150	180	210	240	270	300	330	360	390	420	450
RATE OF DESCENT	m/s	2.2	2.6	3.1	3.5	3.9	4.3	4.8	5.2	5.6	6.0	6.5

Fig. 29. The Sheremetyevo aerodrome ILS Y LOC Y RWY 24L ICAO instrument approach chart

1.11. Flight recorders

The RRJ-95B RA-89098 aircraft had been equipped with the recorders as follows:

– the L3 FA2100 FDR;

– the L3 FA2100 CVR;

– the Integrated Flight Data Management Unit, IFDMU with the Personal Computer Memory Card International Association (PCMCIA) data collecting flash card.

The condition of the recorders, as retrieved from the accident site:

– the L3 FA2100 (PNR 2100-2043-12) FDR had sustained damage. Under the thermal effect the recorder unit case had been partially destroyed (Fig. 30);

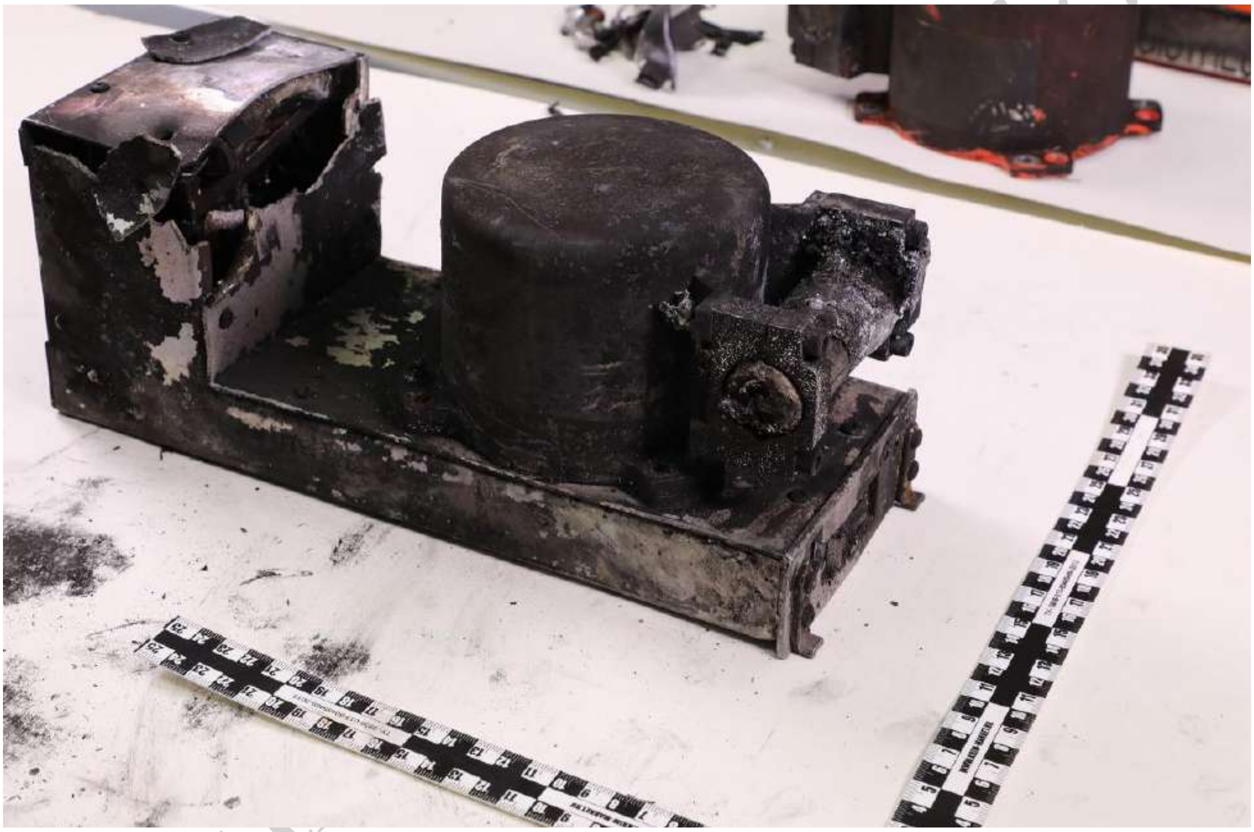


Fig. 30. The L3 FA2100 FDR general view

– the L3 FA2100 (PNR 2100-1025-12) CVR had been subject to damage. The cases of the recorder and the crash-resistant memory module are covered with soot, had not been deformed (Fig. 31);

а) **б)**

Fig. 31. The L3 FA2100 CVR: a) the general view; b) the unit data plate

– the Integrated Flight Data Management Unit (PNR 2235600-06) with the PCMCIA flash card (s/n 2088-51M). The IFDMU case had no visible damage, having been out of the fire seat, had been stated in a satisfactory condition (Fig. 32).

Fig. 32. The IFDMU operational data collecting device with the PCMCIA flash card (# 2088-51M): а) the general view of the unit; б) the unit data plate; в) and г) the PCMCIA flash card (# 2088-51M) on both sides

The decoding of the recorders content had been carried out at the MAK-IAC lab.

The data, pertinent to the flight that ended up with the accident had been preserved. The quality of the record is good.

The record stop by the CVR had occurred at 15:30:53.3. The probable cause of the CVR record stop had been the fire in the F5 compartment, which had damaged the electrical wiring and/or the switchgear that had been fully destroyed by fire.

The record stop by the FDR and IFDMU had occurred just concurrently at 15:31:06-07. The most probable reason for the stop of the recording had been the damage to the electrical wiring at the exposure to fire.

The results of the flight data decoding had been resorted to in establishing the air accident causes and contributing factors.

1.12. Wreckage and impact information

The air accident site inspection had been carried out on May 6, 2019. By the point of the inspection initiation the traces of the first and second touchdowns had not been visible on the runway. To draw up the accident site wreckage map the materials by the Sheremetyevo International Airport, JSC Flight Safety Inspection, as well as the photos and video footage, having been taken right after the air accident had been additionally referred to. Similarly the data by the Sheremetyevo airport CCTV cameras had been used.

As per the footage by the Sheremetyevo airport CCTV cameras the first aircraft touchdown of the RWY 24L occurred at the area of the A8 TWY, at the distance of ≈ 890 m off its entry threshold, having been on the three landing gear legs at once (Fig. 33), followed by the aircraft separation off the RWY (the bounce) (Fig. 34).

Fig. 33. The spot of the aircraft first touchdown on the RWY

Fig. 34. The aircraft separation (the bounce) off the RWY

The second touchdown occurred at the distance of ≈ 1070 m off the RWY 24L entry threshold with the NLG coming first (Fig. 35) with the subsequent touchdown by the MLG legs, which had been followed by another bouncing of the aircraft (Fig. 36). There had been no fuel traces and the aircraft fragments revealed adjacent to the second touchdown spot.

Fig. 35. The spot of the aircraft second touchdown on the RWY

Fig. 36. The aircraft bouncing off the RWY after the second touchdown

The third touchdown occurred at the area of the A7 TWY, at the distance of about 1360 m off the RWY 24L entry threshold, with the right MLG coming first, then the left one with their breaking under (collapse) (Fig. 37).

Fig. 37. The spot of the aircraft third touchdown on the RWY

After the MLG legs collapsed, there occurred the touchdown first by the right engine nacelle, then with the rear fuselage and the left engine nacelle afterwards.

The inspection of the runway right after the air accident had been the evidence that at the distance of ≈ 1360 m off the RWY 24L entry threshold, to the right off the RWY centerline, there had been the traces of the right nacelle and right MLG leg, the left MLG leg inboard wheel and the rear fuselage.

The further movement of the aircraft on the runway had proceeded on the engine nacelles and the rear fuselage with the destruction of the aircraft structural elements, fragments of which had been scattered along the path of the aircraft movement on both sides at a distance of no more than 60 m.

As per the video footage, at the point of the third touchdown, the fuel-air mixture had been released with its flash, the formation of sustained burning had been recorded in about two seconds after.

Initially after the lowering on the engines nacelles the aircraft movement had been a straight line by nature along the RWY axis to the right off it. At the area of the A5 TWY the shift of the aircraft to the left had started with its deviation off the RWY centerline (Fig. 38).

Fig. 38. The starting point of the traces shift to the left off the RWY centerline at the area of the A5 TWY

The aircraft veering off the RWY had occurred at the area of the A3 TWY (at 2460 m off the RWY 24L entry threshold) (Fig. 39).

Fig. 39. The traces of the aircraft movement, the spot of the veering off the RWY at the area of the A3 TWY

The aircraft stop had occurred between TWY 2 and TWY 3 at the point with the reference position: 55°58′06.20″ N, 37°24′07.20″ E, Δh = 185 m, with the true heading ≈ 128° (Fig. 40). The distance off the RWY 24L entry threshold amounted to ≈ 2720 m, the lateral deviation had been equal to about 110 m to the left off the RWY centerline.

Fig. 40. The RRJ-95B RA-89098 airplane at the accident site

After the aircraft had come to the stop, the fire continued on it, having destroyed the major part of the structure (see Section 1.3 of the Report).

Fig. 41 presents the accident site wreckage map.

Fig. 41. The wreckage map of the accident site to the RRJ-95B RA-89098 aircraft at Sheremetyevo airport on May 5, 2019

1.13. Medical and pathological information

After the air accident between 18:40 and 18:45, the flight crewmembers had been subject to the medical examination at the Aeroflot, PJSC medical unit (License # ЛО-77-01-014930 of 03.10.2017 for the right to carry out medical examination to attest intoxication (the alcoholic, drug or the other toxic one). As per the submitted Reports (# 9 for the F/O and # 10 for the PIC), there had been no traces of alcohol in the exhaled breath (the examination had been carried out with the use of the Drager Alcotest 6810 device). The examination to attest the other types of intoxication had not been carried out.

The analysis of the forensic examination reports of the dead bodies of people, having been fatally injured as the outcome of the accident, revealed that the death of all the killed occupants (except for the passenger, who had occupied seat 17E at the rear part of the cabin), having occurred in a relatively short period of time, counted by minutes, had been caused by the thermal injuries of the bodies of varying severity due to the effect of an open flame, accompanied with the burns of the upper respiratory tract through the inhalation of hot air.

The presence of soot in the respiratory tract (in the trachea and bronchi), as well as the presence of carboxyhemoglobin in the blood in various percentages (from 9.0 % to 62 %), demonstrates the lifetime allocation of the fatally injured people in the fire environment.

As per the opinion by the expert, who had been involved in the investigation team activities, in the subject case the poisoning of the killed people by combustion products (by the carbon monoxide, in particular) can be merely interpreted as a factor, contributing to death as the outcome of central nervous system damage (including a potential loss of consciousness). In cases of smoke and fire in a confined space (inside the aircraft passenger cabin, for instance) a high concentration of toxic combustion products is formed in the atmosphere (carbon monoxide, notably), leading to a rapid loss of a person's ability to take adequate actions and the loss of consciousness. It is known that at the content of carboxyhemoglobin in the blood of more than 15%, there is a pronounced toxic effect of this compound on the body, causing oxygen starvation and neuropsychiatric disorder. The higher is the percentage of carboxyhemoglobin in the blood, the longer the person had been allocated alive in the smoke and fire environment (that is, the breathing and blood circulation had been maintained at the person).

In the presence of soot in his respiratory tract carboxyhemoglobin had not been detected in the blood of the passenger, who had occupied the seat 17E in the rear of the cabin, which is a direct evidence that the fatally injured person had been allocated in the seat of the fire at the maintained respiratory functions. In this instance it can be explained by the reflex cardiac arrest, having been the response to a sudden stress situation, whereas the respiratory function had been preserved for a short while[48]. Against this background it can be concluded that this passenger had been dead almost instantly, having been allocated at the seat, namely where his body should have been remained. Indeed, as per the data by the emergency and rescue services at one of the three seats (two seats had been unoccupied) of row 17 along the right side the male burnt body had been discovered.

Note: *Carboxyhemoglobin that binds hemoglobin (the oxygen carrier in the body), features extreme persistence, including to a high temperature. This way, at the examination of the dead body of a man under number 24, who had suffered a 3rd and 4th degree burns of 100% of the body surface, 19% carboxyhemoglobin had been detected in the blood.*

The body of the male flight attendant had been discovered outside of the airplane at 0.5 m off the fuselage opposite the open rear left exit in the pose, specific to the fire (pugilistic attitude/post-mortem «boxer-like» body posture). A relatively small percentage - 15% - of carboxyhemoglobin had been detected in the flight attendant's blood, which evidences his short-term allocation in the seat of fire, having been alive. In view of the stated in Section 1.15.2 of the Report, it may be concluded that he in the conditions of smoke inside the passenger cabin had opened the left rear cabin door, had been subject to intense fire exposure and dead almost instantly.

The bodies of several passengers, advancing towards the exit, had been discovered lying in the aisle in the area of the 6-10 rows of seats. At that, the majority of the passengers' dead bodies had been allocated in the rear of the passenger cabin. The analysis of the results of the forensic medical examination of the fatally injured people showed that the percentage of carboxyhemoglobin in the blood is on average higher to those of them, whose bodies had been revealed closer to the front of the passenger cabin.

1.14. Survival aspects

Prior to departure there had been 78 persons aboard the aircraft, out of whom 5 crewmembers and 73 passengers, including 71 adult passengers and 2 children, aged 11 and 12. The number of passengers aboard the aircraft did not exceed the number of seats in the passenger cabin (the aircraft was operated in a passenger cabin configuration of 75 economy and 12 business class seats). 5 people had been allocated in the business class cabin, 68 people - in the economy class cabin, including 2 children, 14 seats remained unoccupied. As the outcome of the accident 41 people had been killed (out of whom 1 crewmember), 37 persons survived (out of whom 4 crewmembers). Fig. 42 presents the crew and passengers' seating allocation (according to boarding passes) as per the seats in the aircraft passenger cabin with the indication of the air accident

[48] If to exclude the potential error at the performance of the forensic examination.

outcome. The majority of the fatally injured people had been allocated in-flight at the rear of the cabin as from 11th row of the seats, one fatally injured person had seated at row 9 by the cabin window along the right side.

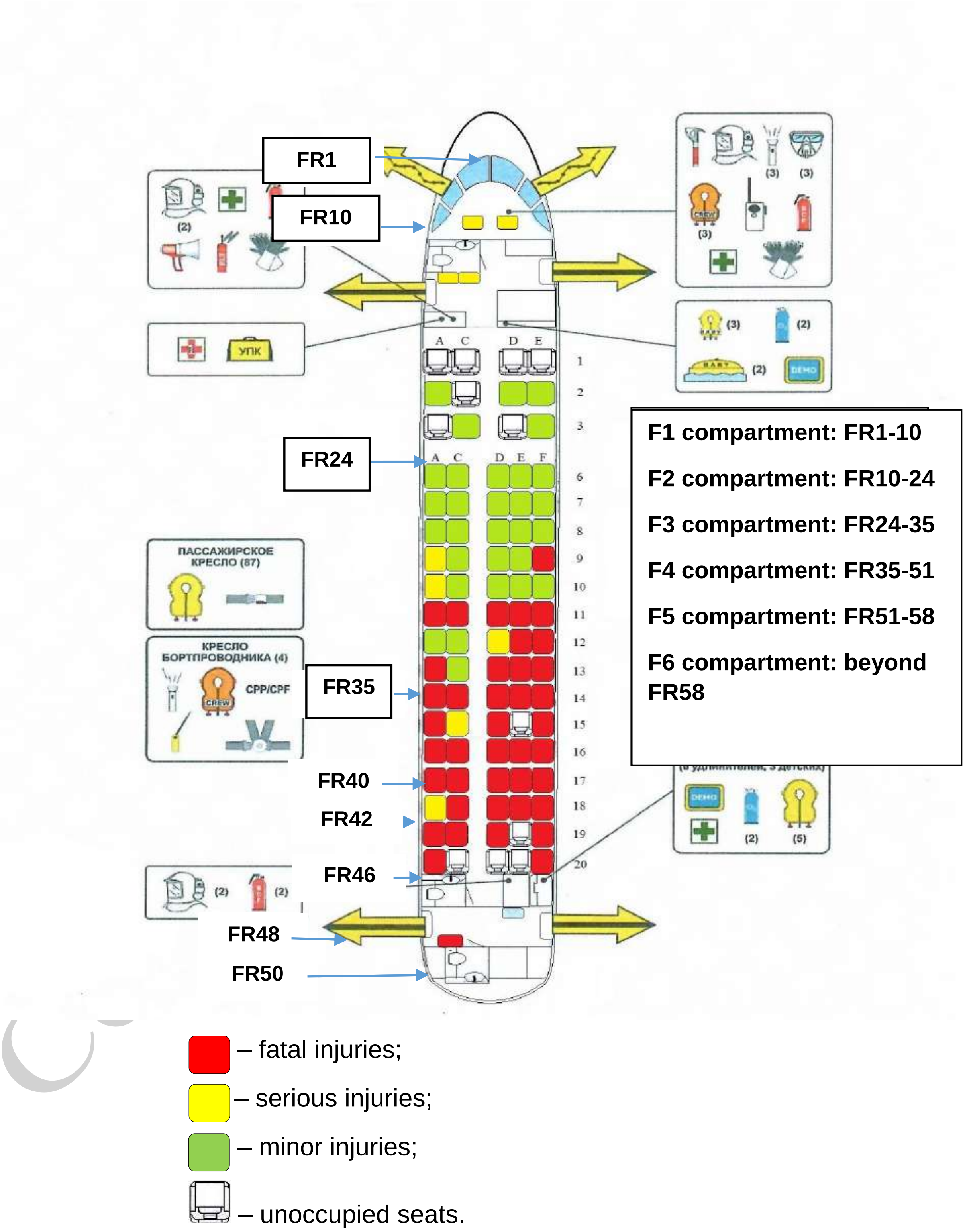


Fig. 42. The crew and passengers' seating allocation as per the seats, the allocation of the board emergency and rescue equipment (the quantity is indicated in brackets) and the numbering of the fuselage sections

5 passengers on the seats 9A, 10A, 12D, 15C, 18A and 4 crewmembers sustained serious injuries as they required hospital treatment for more than 48 hours within seven days after the

accident (item 1.2.2.24 of the Civil Aircraft Accident and Incident Investigation Rules in the Russian Federation of 1998).

28 passengers sustained minor injuries.

In the progress of the investigation no stowaways had been identified on board.

Note: *The appendix to the SU-1492 loadsheet reads data on the scheduled (booked) transportation of 74 passengers (72 adult people, 2 children). These data had not been used to generate loadsheet and the aircraft loading instruction to the SU-1492 flight. The quantity of actually sold tickets and the checked-in passengers amounted to 73 passengers (71 adult people and 2 children) that is confirmed by the passenger manifest. Besides, the data on the payload total weight, included in the loadsheet, as well as in the aircraft loading instruction and report as to the SU-1492 flight contain information on 73 passengers, out of whom 5, allocated in business class cabin, 68 – in economy class cabin.*

1.15. Emergency response

1.15.1. The information on the aerodrome firefighting vehicles, involved in the emergency response

Buffalo FLF 11000 aerodrome firefighting vehicle, garage number 16-770, manufactured in 2011

It was based at the Runway Emergency and Rescue Station-1 (see Fig. 43 here below) with the Strela-1 callsign. It has Certificate of Conformity # ПАСОП ГА.УЧ.11.0019 of February 02, 2012, issued permanent to the vehicle with the WPB93018314546854 VIN.

Note: *Compliant to the Federal Air Transport Service Order # 98 of April 24, 2000 FAR «Certification of Airports. Procedures», the firefighting vehicles operations had been approved with the certificate only. The certification had been carried out by the Civil Aviation Air Operations Firefighting and Rescue Support Service Certification Center for the compliance to the Civil Aviation Air Operations Firefighting and Rescue Support Service Certification Requirements # 80.118-96/1 «Certification Requirements. Aerodrome Firefighting Vehicles», approved by the Federal Air Transport Service general manager on June 10, 1996.*

The Federal Air Transport Service Order # 98 had remained in force until 2015 and had been cancelled by the Russian Federation Ministry of Transport Order # 286 of September 25, 2015 «On the approval of the Federal Aviation Regulations «Requirements for the civil aviation aerodromes operators. The form and procedure of the issue of the document, confirming the civil aviation aerodromes operators' compliance to the Federal Aviation Regulations requirements».

After 2015, the aerodrome firefighting vehicle certificate issuance is not mandatory. The certification of the firefighting vehicles may be carried out on a voluntary basis, based on the request. The certificate of conformity covers only the aerodrome firefighting vehicle, specified in this certificate.

It integrates the tanks for water storage of the capacity of 10400 kg, for the foaming agent storage of the capacity of 1100 kg. The foaming agent type in use is ПО-6РЗФ. The fire suppressant discharge rate is 50/40 kg/sec (via the roof fire barrel/bumper).

The Kronenburg CTO 12 MAC 6*6 aerodrome firefighting vehicle, garage number 16-768, manufactured in 2011

It was based at the Runway Emergency and Rescue Station-1 with the Strela-3 callsign. It has Certificate of Conformity # ПАСОП ГА.УЧ.12.0023 of April 11, 2012, issued permanent to the vehicle with the 1K9AF6680BN058175 VIN.

It is equipped with the water storage tanks of the capacity of 12000 kg, the foaming agent storage tanks with the capacity of 1400 kg. The foaming agent type in use is ПО-6НСВ. The fire suppressant discharge rate is 60/30 kg/sec (via the roof fire barrel/bumper).

The AA-11-100 Panther 6×6 NEW (CA5 HRET 54) aerodrome firefighting vehicle, garage number 17- 776, manufactured in 2016

It was based at the Runway Emergency and Rescue Station-1 with the Strela-5 callsign. It has Certificate of Conformity # ПАСОП ГА.УЧ.16.0109 of December 20, 2016, valid till December 20, 2018. The certificate is issued to this aerodrome firefighting vehicle type. The certificate covered all the aerodrome firefighting vehicles of the indicated type, manufactured within the certificate validity period.

It is equipped with the water storage tanks of the capacity of 11000 kg, the foaming agent storage tanks with the capacity of 1300 kg. The foaming agent type in use is ПО-6НСВ. The fire suppressant discharge rate by the roof (upper) monitor is 50 kg/sec and 83 kg/sec at 16 bar, 58 kg/sec at 10 bar by the bumper monitor.

The RIV 2700 the aerodrome firefighting vehicle, garage number 16-760, manufactured in 2008

It was based at the Runway Emergency and Rescue Station-2 with the Strela-6 callsign. It has Type Certificate of Conformity # 2051080614 of June 02, 2002, valid till July 02, 2010. The latest repair had been carried out in December 2018 at the facilities of the Sheremetyevo International Airport, JSC Wheeled and Tracked Vehicles Repair Service.

It is equipped with the water storage tanks of the capacity of 2500 kg, the foaming agent storage tanks with the capacity of 200 kg. The foaming agent type in use is ПО-6А3F. The fire suppressant discharge rate is 40 kg/sec (via the roof fire barrel).

On March 29, 2019 the FATA commission assessed the vehicle technical condition, as the result of the assessment it was decided to extend the service life by one year till March 29, 2020. At the examination the check run of the vehicle had been carried out, the run time along the straightway of 2000 m distance had amounted to 93 sec. The fire suppressant monitor discharge started in 5 sec. from the moment of arrival on the simulated fire scene. The fire suppressant discharge distance had amounted to at least 55 m.

Note: ***The Federal Antimonopoly Service Order # 102 of April 21, 1999 «On the enactment of the provisions on the operation procedure of the aerodrome firefighting vehicles to the civil aviation air companies»***

item 2.2 The aerodrome firefighting vehicle expected service life extension (beyond 10 years) is carried out individually for each firefighting vehicle in operation for a period of not more than 1 year.

the Civil Aviation Air Operations Firefighting and Rescue Support Service Certification Requirements # 80.118-96/1 «Aerodrome Firefighting Vehicles»

item 2.1: The aerodrome firefighting vehicle run time from the zero speed until the stop along the asphalt or concrete coating straightway of the 2000 ± 50 m distance shall not exceed 90 sec (the light or mid-sized type of the aerodrome firefighting vehicle), the 120 sec timespan is tolerable, and 120 sec (the heavy type of the firefighting vehicle)[49], the 150 sec timespan is tolerable.

item 2.12: The aerodrome firefighting vehicle configuration shall ensure the fire suppressant monitor discharge with nominal output not later than in 15 sec. upon the aerodrome firefighting vehicle arrival to the simulated fire scene.

item 2.13: The distance of the monitor discharge shall be at least 50 m.

The Buffalo FLF 10200/250/120 aerodrome firefighting vehicle, garage number 16-763, manufactured in 2004

[49] Depending on the fire suppressant capacity the aerodrome firefighting vehicles are divided into three types: the light one (the fire suppressant capacity of up to 4000 kg); the mid-sized one (the fire suppressant capacity of between 4000 kg and 10000 kg); the heavy one (the fire suppressant capacity of 10000 kg and beyond).

It was based at the Base Emergency and Rescue Station-2 with the Strela-8 callsign. At the point of the air accident it was at the Runway Emergency and Rescue Station-2, subject then to refilling with water upon the completion of the drill. It has the Certificate of Conformity # 2051061080 of … . The latest repair had been carried out in March 2019 at the facilities of the Sheremetyevo International Airport, JSC Wheeled and Tracked Vehicles Repair Service.

It is equipped with the water storage tanks of the capacity of 9000 kg, the foaming agent storage tanks with the capacity of 1200 kg. The foaming agent type in use is ПО-6НСВ. The fire suppressant discharge rate is 50/40 kg/sec (via the roof fire barrel/bumper).

On March 29, 2019 the FATA commission assessed the vehicle technical condition, as the result of the assessment it was decided to extend the service life by one year till March 29, 2020. At the examination the check run of the vehicle had been carried out, the run time along the straightway of 2000 m distance had amounted to 98 sec. The fire suppressant monitor discharge started in 5 sec. from the moment of arrival on the simulated fire scene. The fire suppressant discharge distance had amounted to at least 55 m.

The AA-12/60 (VOLVO) (AA) aerodrome firefighting vehicle, garage number 16-771, manufactured in 2018

It was based at the Runway Emergency and Rescue Station-2 with the Strela-11 callsign. It has Type Certificate of Conformity # ПАСОП ГА.УЧ.19.0141 of April 08, 2019, valid till April 8, 2021.

It is equipped with the water storage tanks of the capacity of 11300 kg, the foaming agent storage tanks with the capacity of 700 kg. The foaming agent type in use is ПО-6НСВ. The fire suppressant discharge rate is 60/32 kg/sec (via the roof fire barrel/bumper).

1.15.2. The timeline of the evacuation and emergency response

This Section integrates the timeline of the crewmembers and passengers evacuation, as well as the timeline of the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service workforce and means actions. The analysis of the survivability factors is given in Section 2.5 of the Report, the analysis of the cabin crew actions is outlined in Section 2.6 of the Report, the analysis of the emergency and rescue team is stated in Section 2.7.

As per the explanations by the cabin crew survivors, having been allocated on the seats next to the 1L and 1R doors, in the progress of descent for landing the passengers had been occupying their seats with the seatbelts fastened. The flight attendants were allocated at their staff seats (duty stations) with their harnesses and belts fastened. There was no information, communicated by the crew to prepare passengers for emergency landing.

Up to the point of the aircraft landing there had been no information acquired by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service that would require the alerting of the emergency and rescue teams to conduct emergency and rescue operation. Fig. 43 presents the allocation of the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service emergency and rescue stations at Sheremetyevo aerodrome.

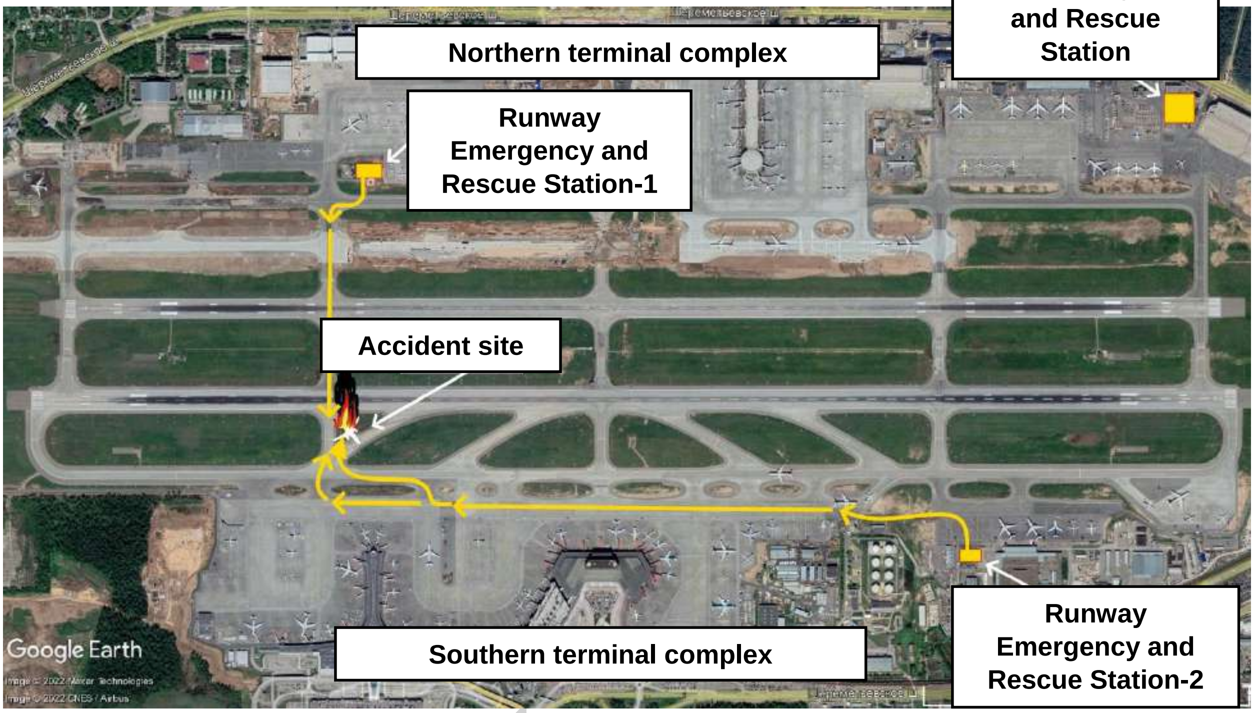


Fig. 43. The allocation of the firefighting vehicles and their movement to the accident site

On May 5, 2019 the duty of the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire rescue crews had been carried out at three emergency and rescue stations, allocated on the perimeter of the runways, having been out of:

– at the Base Emergency and Rescue Station – 2 vehicles: the Strela-8 aerodrome firefighting vehicle (actually at the point of the air accident it had been at the Runway Emergency and Rescue Station-2, having been subject the water replenishment upon the completion of the drill) and the Strela-9 Gas and Smoke Protection Service vehicle;

– at the Runway Emergency and Rescue Station-1 - 3 vehicles: the Strela-1, Strela-3 and Strela-5 aerodrome firefighting vehicles;

– at the Runway Emergency and Rescue Station-2 - 2 vehicles: the Strela-6 and Strela-11 aerodrome firefighting vehicles.

The fire to the airplane had broken out after the third touchdown (landing) of the runway (at 15:30:06) and at its onset had been the deflagration[50] flash by nature, which had been

[50] See Section 1.16.18 of the Report as well.

accompanied with an intense smoke release with the onset of a steady burning in two sec. approximately.

The emergency had been first reported by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service fire and rescue division sector crew leader, who had been replacing the observer at the Runway Emergency and Rescue Station-1 lookout tower: *«Emergency, traffic on the runway»*. Later at 15:30:27 he communicated: *«Emergency, did you copy? The fourth runway the traffic on fire on the runway»*.

Note: *1. The Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service fire and rescue division sector crew leader had been at the observer's duty station over his break for supper. The emergency had been identified by him by the strong bang and the airplane in sight, «having glided» in flames on the runway. He declared Alarm to the Runway Emergency and Rescue Station-1 personnel with the use of the alarm button and by the voice through the public address system, before having received the Alarm signal from the air operations supervisor. After that he had deployed to the accident site in the Strela-3 aerodrome firefighting vehicle crew.*

2. The «fourth runway» stood for the RWY 24L, on which the aircraft had landed.

At 15:30:23 a no-addressee command had been relayed at the 121.5 MHz emergency frequency: *«The emergency services are called to the runway»*. There is no way to determine who had been the issuer of this command.

The utterances as follows had been recorded by the CVR[51]:

– at 15:30:33 the CFA: *«Fire!»*;

– at 15:30:38 (the point of the aircraft stop as by the recorders data) the F/O issued the command: *«Attention crew! On station. Attention crew! On station»*. By this command the cabin crew should have checked the door selector position, assess the environment inside and outside the aircraft to report to the flight crew. Still, as indicated in Section 1.18.25, this command had been actually relayed by the F/O through the VDR 2, that is it could not have been heard by the flight attendants;

– at 15:30:30 the CFA: *«Fire on board!»*

– at 15:30:40 the F/O: *«Evacuation!»*

– at 15:30:46 the flight attendant from the rear passenger cabin: «We are on fire!».

[51] See Section 1.18.25 of the Report.

According to the FDR data, the opening of the right service door (1R) had been performed at 15:30:46. This is as well evidenced by the analysis of the video footage. As per the explanatory notes the door had been opened by a cabin crewmember, having been in charge of this exit. The escape slide had been fully inflated in 4 sec. (at the maximum allowed time of 10 sec.).

Note: *For each of the 1L, 1R, 2L, 2R door the FDR records the data word out of three bits. The second and third bits of the data word are set to «1», if the door retaining pins proximity sensor and the door locks proximity sensor unlocked position is respectively detected. The first bit is set to «1» (the door opened), if either of the bits 2 and 3 is set to «1», or if both bits are set concurrently.*
For each out of two baggage doors the FDR records the data word out of five bits. The setting of the bits to «1» proceeds with the same logic given that there are two locks on each cargo door.

At 15:30:49 the command by the one of the flight attendants is recorded by the CVR: *«Seat belts off, leave everything, get out!»*.

At 15:30:52 the follow-up command «*Evacuation»* by the F/O is recorded by CVR.

Meanwhile the data started to be recorded by FDR, indicating the opened position of the rear baggage compartment and rear service (2R) doors. At the post-accident inspection of the aircraft it had been determined that the mentioned doors had been observed closed. In this way the information, recorded by the FDR on the condition of the rear baggage compartment and rear service doors, is invalid, which had been the result of the respective sensors and signal transmission circuits exposure to fire.

At 15:30:53, in 3 sec. after the 1R door escape slide setup to the operating position, the passengers began to leave the aircraft.

At 15:30:55 (as by FDR) the 1L front cabin door was opened. This evidenced as well by the video footage analysis. The 1L door escape slide inflated in 5 sec., the first passenger left the aircraft by this door at 15:31:09.

At 15:30:58 (in 20 sec. after the aircraft stop) the discrete signals started to have been recorded by the FDR: the opening of the 2L rear cabin door and the opening of the front baggage compartment door, concurrently the record of «1» was «removed» in the bit, indicating the unlocked position of the 2R door locks by the proximity sensor (at that the data by the proximity sensor on the door retaining pins unlocked position and, accordingly, on its unlocked position continued to be recorded).

As set forth above, the 2R door had not actually opened, the front baggage compartment door had been detected closed after the accident. Thus, the recorded information to the 2R door and front baggage compartment door is invalid and is the result of the respective sensors and signal transmission circuits exposure to fire. Based on stated, as well as on the fact that all three discrete signals had passed simultaneously, the data on the opening of the 2L door at this particular point of time may be invalid as well. At that after the accident the 2L door had been revealed opened. It is not possible to determine the exact point of time, when it had been opened.

At 15:30:58 via the Air Operations Search Emergency and Rescue Support Service channel it had been the report by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service Emergency and Rescue Response supervisor: *«Declare Alarm! To all the vehicles, all the firefighting vehicles are called to the 24th left immediately!»*. In a second after that via the Air Operations Search Emergency and Rescue Support Service channel the Sheremetyevo International Airport, JSC officer to the emergency calls receipt and processing communicated: *«Attention! The Alarm is declared to the emergency and rescue teams, the code «Red». Superjet, the Aeroflot airline, at the landing due to the technical reason is on the second «Alpha», catching fire».*

Meanwhile (at 15:30:58) via the Gorn emergency alert system the air operations supervisor declared Alarm of code «Red» to the emergency and rescue teams (the air occurrence within the air operations emergency and rescue support area of responsibility at the airport or at the aerodrome area): *«Attention, the Alarm is declared to the emergency and rescue teams, the code «Red». The Aeroflot airline Sukhoi Superjet aircraft while on landing, as the result of the non-normal landing, the aircraft performed the non-normal maneuver and caught fire, the air operations are stopped. To all stations switch to the emergency channel. The aircraft is on the Alpha-3 taxiway. Fire».*

Note: *The difference in the indication of the aircraft allocation against the taxiways (A3 and A2) could not have affected the aerodrome firefighting vehicle crews in determining the muster point for emergency and rescue response: the aircraft had been on the soil between A2 and A3 taxiways.*

The flight attendant and the CFA left the aircraft at 15:31:28 and 15:31:39 respectively.

At 15:31:34 approximately – the point of the engines shutdown[52].

At 15:31:50 the report by the Strela-8 aerodrome firefighting vehicle crew that had deployed to the accident site from the Runway Emergency and Rescue Station-2 is recorded: *«Sirena – Strela-8, proceeding to the site. Heavy smoke in sight, the black one, and flames. How did you copy, over? Call for additional garrison forces and ambulance».*

[52] The average time of the rotors run-on after the shutdown from the idle amounts to about 1 min. 30 sec.

At 15:31:53 the Sheremetyevo Handling, LLC vehicle, which happened to be nearby, arrived at the accident site at one's own instance. As explained by the vehicle driver, he had driven up to the airplane before the arrival of the firefighting vehicles, assisted the evacuated passengers.

The Strela-3 aerodrome firefighting vehicle had been the first to arrive at the accident site at 15:32:07 and it had immediately started extinguishing the fire. The timing of the arrival of the Air Operations Search Emergency and Rescue Support Service forces and means is given in the Table here below.

The arrival time[53]	**The vehicle and Runway Emergency and Rescue Station, from which it had arrived to the accident site**
15:32:07	«Strela-3» from Runway Emergency and Rescue Station -1
15:32:25	«Strela-1» from Runway Emergency and Rescue Station -1
15:32:43	«Strela -5» from Runway Emergency and Rescue Station -1
15:33:15	«Strela -11» from Runway Emergency and Rescue Station -2
15:33:52	«Strela -8» from Runway Emergency and Rescue Station -2
15:33:52	«Strela-6» from Runway Emergency and Rescue Station -2
15:36:11	Strela-9 Gas and Smoke Protection Service vehicle from Base Emergency and Rescue Station

Over 15:32:17 - 15:33:00 the information had been submitted to and the call of the additional forces had been made of the Moscow region Crisis Management Center, the Khimki firefighting unit and Emergency and Rescue Service duty and dispatch service, MSFI.

After the flight attendants left the aircraft, 4 more passengers, assisted by the flight crewmembers, who remained on board, and one of the passengers, were evacuated from the aircraft through the 1R door (including the one who assisted in the evacuation). The last passenger left the

[53] The time of the stop of the respective aerodrome firefighting vehicle is indicated.

aircraft by the 1R door at 15:32:32. It had been 106 sec. between the 1R door opening point and the point when the last survived passenger left the aircraft.

A total of 24 passengers left the aircraft by the 1R door and 9 passengers did by the 1L door.

The first attempt by the firefighters to get into the aircraft by the 1R door was recorded at 15:32:53. However, the firefighter was unable to climb the escape slide.

The F/O left the aircraft at 15:33:07 by the escape rope through the right cockpit window.

As per the video footage, available to the investigation team, the F/O's return to the aircraft by the 1R door escape slide at 15:33:50 had been captured.

Note: *It had not been possible to reliably identify the purpose of the F/O's return to the aircraft. After returning to the aircraft, the F/O went into the cockpit and threw several items out of the aircraft. As explained by the PIC, it was the EFBs bag and his raincoat.*

Over 15:33:53 – 15:39:32 all the emergency and rescue teams out-of-staff crews arrived to the accident site.

Compliant to the Sheremetyevo International Airport, JSC Emergency Response plan, at 15:34 the airport shift supervisor initiated the following procedures:

- the treatment of the people, who had escaped unharmed;
- the treatment and transport of those, having escaped unharmed;
- the arrangement of the information center operation;
- the service to the accompanying persons and relatives.

The second time the F/O left the aircraft by the 1R door escape slide had been at 15:34:15.

The Air Operations Search Emergency and Rescue Support Service emergency calls receipt and processing officer had transmitted the information on the number of the people on board to the firefighting crews over 15:35:00 – 15:35:38 (in about 3 minutes after the arrival and deployment of the first firefighting vehicle):

«15:35:00 Sirena to Sokol. We are operating with four barrels to extinguish. The flame is still here, no passengers in sight, the evacuated passengers.

15:35:16 Roger, no passengers and evacuated people in sight. Did I read correctly?

15:35:22 Affirm, not yet, not yet, unable to tell the number of passengers, where they are.

15:35:31 I have the number of passengers reported, 73 passengers».

At 15:35:04 the EMERCOM crew arrived at the accident site.

To get inside the aircraft the arrangement of two Gas and Smoke Protection Service squads was initiated. At 15:35:38 the Strela-8 vehicle fire escape ladder was installed at the 1R exit. At

15:35:44 the rescuer of the first squad to the Gas and Smoke Protection Service got inside the aircraft.

Between 15:36 – 17:00 the emergency medical assistance was provided to the injured people with their transport to the Krasnogorsk and Khimki town hospitals.

Commanded by the Gas and Smoke Protection Service squad firefighter, the PIC left the aircraft at 15:36:12 through the 1R door by a straight ladder.

At 15:36:51 Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service airport fire department firefighting division sector team leader relayed via the Air Operations Search Emergency and Rescue Support Service channel: *«Sirena, so, the Gas and Smoke Protection Service squad is getting inside the aircraft with the hand branch pipes, the hand branch pipe and one hand branch pipe has been deployed to eliminate fire under the aircraft fuselage. How did you read? The aircraft nose section is still intact».*

At 15:41:43 the fire had been isolated.

At 15:42:43 the Gas and Smoke Protection Service second squad getting inside the aircraft, the extinguishing of the fire inside the fuselage and no fire outside the aircraft had been reported.

At 15:48:00 the fire had been extinguished, till 16:00 the passenger cabin had been washed down.

1.16. Tests and research

1.16.1. The examination of the fuel

To carry out the examination the fuel samples had been taken out of the aircraft wing and the fuel storage tank. The fuel samples had been subject to examination at the State Scientific Research Institute for Civil Aviation, FSUE Airport Operations and Aviation Fuel Supply Scientific Center (Scientific Center-28). The fuel has been stated conditioned.

1.16.2. The examination of the Engine Interface Units/EIU

The Engine Interface Units EIU-100, manufactured by Ulyanovsk Instrument Design Bureau, JSC (part number: КИВШ.466525.019, the software ID: КИВШ.00886), enable the data exchange between the aircraft systems that are not directly interconnected. The aircraft set integrates two interchangeable interface units (hereinafter referred to as the units). There is no data exchange between the units. The unit is an integration of two independent A and B computing channels in one casing. The unit operation modes do not depend of its number in the aircraft set (the installation allocation aboard the airplane). The units are powered by four independent electric buses, which prevents the simultaneous power supply interruption to two EIU-100 units at the power supply system failure. The design of the EIU-100 is made, compliant to the ГОСТ/all-Union State Standard 26765.16-87 and ARINC-600 requirements to the 4MCU form factor. The unit belongs to the III class aircraft components – the category A components and is approved in compliance to AR-21.

Note: *In accordance with the AR-21 item 21.26(3), the category A III class components shall be subject to mandatory qualification in compliance to the procedures, set out by the AR Section O, with the issuance by the competent authority of the Qualification Tests Validity Certificate. Under the КТ-160D qualification requirements «The operating and environmental conditions of the aircraft avionics (the external impact). The test requirements, codes and methods» the EIU-100 unit is qualified in category A2J-32 under Section 22.0 «Lightning-induced transient susceptibility».*

The units ensure the following:

I. The data acquisition, their conversion to the specific layouts and the information output to the aircraft systems via the code communication and discrete signals lines.

II. The algorithmic data processing and the output of the processed data to the aircraft systems via the code communication and discrete signals lines.

III. The interchannel parameters comparison, preceding the output.

IV. The performance of the parameters conversion functions for the maintenance of the aircraft systems that are not directly connected to the aircraft onboard maintenance system.

V. The conversion of the command and data words for the data exchange arrangement for the maintenance system between the avionics system and the APU control system.

VI. The system health built-in test and the information output of the failures to the onboard maintenance system.

The units output the discrete signals to the following aircraft systems:

– Engine Controls ATA 76-00-00;
– AC Generation ATA 24-20-00;
– Exterior Lighting ATA 33-40-00;
– Air Conditioning ATA 21-00-00;
– Cockpit Windshield Electrical Heating ATA 30-41-00;
– Pitot and Static Heating ATA 30-31-00 (as a part of avionics);
– Instrument and Control Panels ATA 31-11-00;
– Multifunctional Transponder ATA 34-57-00.

The crew does not control the units. The information on the unit(s) failures is not displayed to the crew. At the unit(s) failures the crew is delivered the information on the failures to the respective functions and the systems, interacting with the units.

The examination of the EIU-100 had been carried out at the Aviapribor-Service/Air Instrument Service, JSC and the Ulyanovsk Instrument Design Bureau, JSC, having been attended by the IAC, FATA, SCAC, JSC and Aeroflot, PJSC representatives. This included the long-term memory readout and data analysis. On the results of the activities the document, titled «Report on the results of the EIU-100 КИВШ.466525.019 long-term memory readout and data analysis to the RRJ-95 RA 89098 aircraft air accident on May 5, 2019» had been drawn up.

Based on the results of the units' long-term memory readout and data analysis the Report states the findings as follows:

1) The channels B to both units had functioned as designed into the entire flight till the point of landing.

2) Till the point of landing the channels A do not contain the event codes that would indicate the channel fault.

3) In the channels A to both units within 15:08:06 – 15:08:24 (the time record sampling rate is 6 sec.) it had been the occurrence of transition (reboot) to a new long-term memory sector with the interruption of the processing unit operation for the time of ≈ 18 sec. This transition could have been induced either by the power failure at the units channels A input, or a short-term fault to the units channels A.

4) The present event codes, recorded in units both channels after the time of 15:30:24, are most probably associated with the post-landing aircraft destruction.

The analysis of the RRJ-95B aircraft avionics systems fail-safety the failure (including the reboot process) of the EIUs results, inter alia, in the FBWCS reversion to minimum mode (DIRECT MODE).

It should be pointed out as well that in the progress of the examination it had not been possible to accurately replicate the situation of the A channels reboot by exposing the EIUs to the electric discharges of different power.

1.16.3. The replication of the in-cockpit indication at the EIUs reboot

On the investigation team request, the aircraft designer had carried out the examination at the Electronic Bird bench to replicate the in-cockpit indication and the behavior of the aircraft systems at the short-term data loss out of the EIU-100. In the progress of the activities both the total loss of signal out of the EIU-100 and the loss of signal out of the A channels with the subsequent signal recovery had been simulated with the video record of the in-cockpit indication and the data record to the IFDMU. The analysis of the parameters, recorded by the RA-89098 recorders and the Electronic Bird bench had shown the similarity of the systems behavior at the short-term data loss out of the both units A channels. A presumed list of the CAS messages had been also determined, which had been displayed to the crew at the reboot and after the EIU-100 normal operation had been resumed. On the results of the works the relevant technical report had been drawn up.

The analysis of the performed works revealed that the convergence of the recorded occurrences and systems behavior in the experiment and into the flight that had ended up with the accident is enabled at the reboot[54] of two EIU-100 A channels. At that during the test on the total power-off of two EIU-100 the acquired results had been different from the record of the flight that had ended up with the accident.

Based on the experiment it had been stated that at the short-time data loss out of the A channels to both EIUs the following CAS-messages are displayed to the crew (as shown in the Table here below). The cell background color is consistent with the message «severity» color coding: the red one is for Warning, the amber for Caution, the white color is for Advisory. The messages are presented in order of their display[55]. All messages, except for the last two, had been displayed with the EIUs power supply interruption, the last two messages had appeared delayed by about 5 sec., which is in line with their generation logic.

CAS-message	**The decoding (as per M7.92.FCOM.000.AFL.RU, revision 115)**
AUTO FLT AP OFF	The AP failure or disconnect
F/CTL DIRECT MODE	The reversion to DIRECT MODE
F/CTL FLP/SLT PROT FAULT	The failure of the flaps/slats protection
F/CTL ALF A/G PROT DEGRAD	The degradation of the AOA and G limitation functions
F/CTL AUTO SPD BRK FAULT	The failure of the speedbrake and spoilers automatic control
AUTO FLT APPROACH1 FAULT	The CAT 1 approach is not enabled
AUTO FLT APPROACH2 FAULT	The CAT 2 approach is not enabled
AUTO FLT FD FAULT	The FD failure
CAB PRESS A-MODE FAULT	The failure of the cabin pressure control system automatic mode

[54] The reboot had been simulated with the concurrent power-off and the subsequent simultaneous resumption of two EIU-100 A channels power supply.
[55] The messages had been displayed to the crew by priority: red – Warning, amber – Caution, white – Advisory. At the display of a new higher priority message it automatically tops the lower priority messages.

After the power supply was resumed and until the end of the flight the following messages had remained displayed:

CAS-message
AUTO FLT AP OFF
F/CTL DIRECT MODE
F/CTL FLP/SLT PROT FAULT
AUTO FLT APPROACH1 FAULT
AUTO FLT FD FAULT

1.16.4. The examination of the Engine Control Units/ECU

The examinations were carried out by the representatives of IAC, BEA and Safran Electronics & Defense, being the equipment manufacturer, at the BEA facilities (Le Bourget, France).

The ECU is a dual module computer performing fuel and engine parameters management. On each module failures can be stored on a non-volatile memory component for maintenance purposes.

The ECU record a leg number which is the unique one for each flight and is incremented for each flight. For each error, the ECU record the UTC time when the failure triggers and the UTC time when the failure is not present anymore.

ECU #1 (left)

The ECU was in good condition but traces of fire (soot) were present. The computer was opened, two memory boards (for channel A and B) were removed.

The visual inspection of the memory boards revealed that this to the B channel is in good condition. The channel A memory board integrated one failed (mechanically broken) component (the inductance). The analysis showed that this component is not involved in the procedures to download the data. It was decided to download the recorded data by the standard procedure.

The memory boards were installed in the golden unit. The data were successfully downloaded.

The leg number corresponding to the flight of the event was 115. The failures were recorded to it that are given in the Table here below. The timestamp of the record ending to some occurrences is set as «wrong date» because after 15:31:06 the ECU stopped recording the UTC time. Failures that have no information in the Ending column remained active until the end of the record.

Name of the failure	Beginning	Ending	Channel

EIU A PT invalid	15:08:18	15:09:24	A and B
EIU A Pamb invalid	15:08:18	15:09:24	A and B
EIU A TAT invalid	15:08:18	15:09:24	A and B
EIU Ch. A Fault	15:08:18	Wrong date	A and B
DCV or PL Right failed in open position	15:30:06	Wrong date	A and B
T/R system failed to stow	15:30:12	Wrong date	A and B
Reverse Unlocked	15:30:12		A and B
PLU switch failed in unlocked position	15:30:12		A and B
PLL switch failed in unlocked position	15:30:12		A and B
TLL failed in unlocked position	15:30:12		A and B
T/R PLL SW disagree	15:30:30		A and B
115V unavailable to Ignition #2	15:30:54	15:31:06	A and B
Cross channel AC supply fault	15:31:06		A
Local channel AC supply fault	15:31:06		B
No Data from EOSU ChB	15:31:06	Wrong date	A and B
EIU B PT invalid	15:31:06		A and B
EIU B Pamb invalid	15:31:06		A and B
EIU B TAT invalid	15:31:06		A and B
115V unavailable to Ignition #1&2	15:31:06		
No Data from Both EOSU Channels	Wrong date		A and B

Aircraft Type Disagree	Wrong date		A and B
Local channel AC supply fault	Wrong date		A
Cross channel AC supply fault	Wrong date		B
ADIRU 3 PT invalid	Wrong date		A and B
ADIRU 3 Pamb invalid	Wrong date		A and B
EIU Ch. B Fault	Wrong date	Wrong date	A and B
ADIRU 3 TAT invalid	Wrong date		A and B
EIU Ch. A & B Fault	Wrong date		A and B

The description of the failures:

EIU A PT invalid: the Total Pressure data received on ARINC Label 242 from ADIRU#1 through EIU channel A are invalid.

EIU A Pamb invalid: the Ambient Pressure data received on ARINC Label 246 from ADIRU#1 through EIU channel A are invalid.

EIU A TAT invalid: the Total Air Temperature data received on ARINC Label 211 from ADIRU#1 through EIU channel A are invalid.

EIU Ch. A Fault: acquired EIU ARINC channel A lost on DECU channel considered.

DCV or PL Right failed in open position: when TR is commanded stowed (TLA in forward range), the system pressurized and the right RVDT indicates doors unstowed for 5 seconds, the DECU shall send to maintenance the message «DCV or PL right failed in open position».

T/R system failed to stow: when the ICU is energized (ISV = 1 and ICU not failed), the T/R is commanded to stow (DSV = 0) and the Pressure switches indicate «pressurized», the time T/R to become «Locked» shall be monitored. If the time exceeds 6.96 seconds then the message «T/R SYSTEM FAILED TO STOW» shall be sent.

Reverse Unlocked: the REV_UNLOCKED warning is triggered when at least two of the following conditions are met on the same door:

- «RVDT is seen unlocked»;
- «Upper Stow/lock switches failed in unlocked position»
- «Lower Stow/lock switches failed in unlocked position»

- «TL switches failed in unlocked position».

The REV_UNLOCKED warning is triggered on ground when at least one of the following conditions is met:

- «Upper Stow/lock switches failed in unlocked position»
- «Lower Stow/lock switches failed in unlocked position»
- «TL switches failed in unlocked position»
- «ARC failed to stow».

PLU switch failed in unlocked position: when the ICU is not commanded and the DSV has not been commanded 120ms before, and the upper stow/lock switch is declared unlocked, the DECU shall send to maintenance the message «UPPER STOW/LOCK SWITCH FAILED IN UNLOCKED POSITION».

PLL switch failed in unlocked position: when the ICU is not commanded and the DSV has not been commanded 120 ms before, and the lower stow/lock switch is declared unlocked, the DECU shall send to maintenance the message «LOWER STOW/LOCK SWITCH FAILED IN UNLOCKED POSITION».

TLL failed in unlocked position: when both TL Left switch channels are failed or non-available, the message «TL LEFT FAILED IN UNLOCKED POSITION» shall be sent to maintenance.

T/R PLL SW disagree: Thrust Reverser Stow Lower Position switch on channel A and on channel B disagree. One indicates Thrust Reverser is in closed position whereas the other indicates Thrust Reverser is not closed.

115V unavailable to Ignition #2: DECU detects power supply for ignition 2 (Right) is not available when Engine Master Lever is ON.

Cross channel AC supply fault: Aircraft voltage is present when the level exceeds 88 volts RMS for at least 30 milliseconds, and transition to indicate that voltage is not present when the level goes below 15 volts RMS for at least 30 milliseconds.

Local channel AC supply fault: Aircraft voltage is present when the level exceeds 88 volts RMS for at least 30 milliseconds, and transition to indicate that voltage is not present when the level goes below 15 volts RMS for at least 30 milliseconds.

No Data from EOSU ChB: DECU channel A or channel B does not receive ARINC data from EOSU channel B.

EIU B PT invalid: the Total Pressure data received on ARINC Label 242 from ADIRU#2 through EIU channel B are invalid.

EIU B Pamb invalid: the Ambient Pressure data received on ARINC Label 246 from ADIRU#2 through EIU channel B are invalid.

EIU B TAT invalid: the Total Air Temperature data received on ARINC Label 211 from ADIRU#2 through EIU channel B are invalid.

115V unavailable to Ignition #1&2: DECU detects power supply for both ignition 1 (Left) and ignition 2 (Right) is not available when Engine Master Lever is ON.

No Data from Both EOSU Channels: DECU channel A or channel B does not receive ARINC data from both EOSU channel A and channel B.

Aircraft Type Disagree: Engine Thrust Class as read by DECU from Engine Identification Plug is not suitable to aircraft Type as sent by aircraft to DECU via ARINC.

ADIRU 3 PT invalid: the Total Pressure data received on ARINC Label 242 from ADIRU # 3 are invalid.

ADIRU 3 Pamb invalid: The Ambient Pressure data received on ARINC Label 246 from ADIRU # 3 are invalid.

EIU Ch. B Fault: acquired EIU ARINC channel B lost on DECU channel considered.

ADIRU 3 TAT invalid: the Total Air Temperature data received on ARINC Label 211 from ADIRU # 3 are invalid.

EIU Ch. A & B Fault: acquired EIU ARINC channel A and acquired EIU ARINC channel B lost on DECU channel considered.

ECU #2 (right)

The ECU was in good condition. The computer was opened, the two memory boards (for channel A and B) were removed.

The visual inspection of the memory boards revealed that they are in good condition. It was decided to download the recorded data by the standard procedure.

The memory boards were installed in the golden unit. The data were successfully downloaded.

The analysis was the evidence that there is no information related to the accident flight in the downloaded data set. For a possible explanation of this fact, the conditions under which the messages are recorded to the non-volatile memory after the flight were subject to analysis.

On PowerJet SaM 146 engines, NVM messages are not recorded in a continuous mode, the DECU is waiting for the end of the mission to command the NVM writing of all the messages «collected» during the flight and which are meanwhile stored in a RAM.

The writing operation in the NVM is done if the HP rotation speed is seen less than 3000 rpm after being seen higher than 6000 rpm, this indicates the end of a mission. If the rotation speed is never measured below 3000 rpm by DECU there is no NVM recording and the data in RAM are lost (after the power supply is lost).

During a flight leg, if the aircraft power supply (115 volts) is not available, then the DECU is power supplied by the PMA until this one is still able to provide sufficient power, depending on the engine rotation speed. The PMA is specified to power supply the EEC from 5782 rpm (~38 %) and it is able to operate below this speed because of conception margins. However around 3000 rpm (~20 %) the PMA may or may not be able to power supply the DECU depending on PMA and DECU dispersions.

That means that at the N_2 speed of 3000 rpm and less, without 115 V power supply from aircraft buses, the success of DECU NVM writing is not guaranteed, as the PMA output power could be insufficient to enable the DECU operation.

Thereby the most likely scenario of non-writing fault messages in the NVM to the ECU # 2 (right) was a loss of 115 V power supply on the DECU before the DECU see the passage of the HP rotation speed under 3000 rpm, no more PMA power supply available due to low rotation speed (3000 rpm) → no NVM recording.

Summary on the results of the examination[56]

Until the exposure to the atmospheric electricity the engines had functioned as assigned.

The first group out of 4 messages (failures) (the record starting from 15:08:18) was recorded after the exposure to atmospheric electricity and was caused by the reboot of channels A of the EIUs (see Section 1.16.2 of the Report as well). After the completion of the reboot 3 out of 4 stated messages were no longer active, the fourth one («EIU channel A Fault») remained active till the end of the flight.

The one channel loss of parameters of the total air pressure and ambient pressure, as well as the total air temperature, delivered by the aircraft systems, did not anyhow affected the engines operation. The present redundancy of the stated parameters was enough. There had been no engines transition to the alternate law. Till landing the engines functioned as assigned.

The second group of messages (the record starting from 15:30:06) is derived from the failure of the TR doors to operate as assigned, associated with the aircraft lowering on the engine nacelles after hard touchdowns and destruction of the landing gear structure.

The third group of messages (the record, starting from 15:30:54) is, most probably, associated with a number of systems power off as they sustained damage in the ongoing fire.

Till the end of the record both engines were running, the position of the engine master levers was recorded ON.

[56] Based on the data, recorded by the aircraft recorders.

1.16.5. The examination of the Central Processing Module/CPM

The examination was held at the Thales facilities (Chatellerault, France), attended by the IAC and BEA representatives.

CPM is a computer dedicated to the maintenance and warning processing. This computer hosts the following applications:

- FWA: Flight Warning Application
- CMA: Centralized Maintenance Application
- SWA: Stall Warning Application
- DCA: Data Concentration Application
- SBITE: System BITE
- ADN: AFDX network agent

The computer incorporates the NVM that records the monitored systems failures as well as CPM internal failures.

The internal failures related to CPM itself failures or failures detected by hosted applications are first stored in a temporary area in the NVM.

All monitored avionics systems send failures to the CMA application. These failures are first stored in a volatile memory inside the CPM.

After landing, once the airplane is on ground with a speed lower than 60 kt for more than 30 seconds (i.e. 30 seconds with **Taxi in** flight phase activated, see Fig. 47), all the failures stored in the volatile memory by the CMA are transferred to the NVM. In addition, failures stored in the temporary area of the NVM are moved to their definitive location in the NVM (i.e. SBITE).

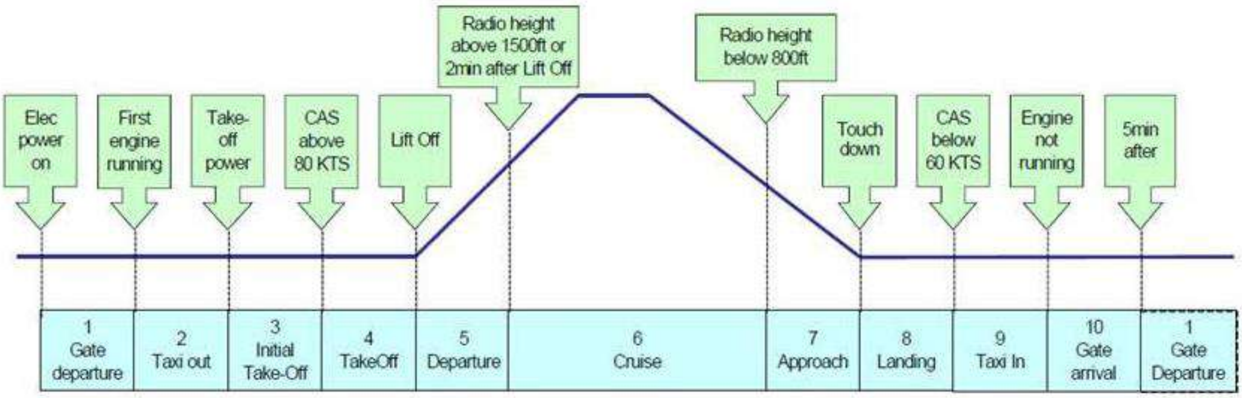


Fig. 44. The flight phases and the conditions for their generation

There are two CPM installed onboard the aircraft. Both CPM were observed in a good condition. The NVM was downloaded by a standard procedure.

The analysis indicated that the NVM does not integrate failures, related to the monitored systems. This is most likely due to the fact that into the flight that ended up with the accident the Taxi In had not been generated, therefore the information from the NVM had not been written (transferred) from the volatile memory to the non-volatile one and had been lost after the computers power off.

The NVM temporary area to both CPM, where the internal failures are recorded to, 4 identical failure messages were detected to both CPM, as described in the Table below.

The name of the failure	The beginning of the record[57]	The end of the record	The source of the message
BAT1_OVERHEAT_EIU_2	15:08:06	15:08:30	FWA
BAT1_OVERHEAT_EIU_1	15:08:06	15:08:24	FWA
VDR1 not healthy	15:09:06	Until the end of the flight	CMA
Inputs monitoring STALL DEGRADED	15:30:05	Until the end of the flight	SWA

The first two messages indicate that the CPM detected the inconsistency of the signals of the battery 1 overheat by both EIU. Apparently their occurrence is associated with the EIUs reboot (see Section 1.16.2 of the Report).

The third message demonstrates the VDR1 failure. This failure is supported, inter alia, by the results of the subject VDR examination (see Section 1.16.7 of the Report).

The fourth message witnesses the degradation of the functionality of the stall warning system. This message appeared after the third touchdown and may be associated with the falsity of the AOA signals after the destruction of the aircraft MLG legs.

1.16.6. The examination of the Generator Control Unit/GCU and Generator Auxiliary Power Control Unit/GAPCU

The examination was carried out at the facilities of the equipment designer - Collins Aerospace in Dijon, France with the participation of the IAC and BEA representatives.

The Generator Control Unit/GCU monitors the generator condition. There are two subject units installed aboard the aircraft – to left and right engine. The unit checks the power quality (the voltage, frequency and current) is within the tolerances. If there is the occurrence of any anomaly or short-circuit, the GCU isolates generator from the electrical circuit. The unit integrates the NVM, to which the occurrences (failures) are recorded with the attribution of the UTC date and time.

The Generator Auxiliary Power Control Unit/GAPCU performs the same functions relative to the APU.

GCU #1 (left)

[57] The accuracy (sampling rate) of the timestamp record is 6 sec.

The unit was observed in a good external condition. The electrical condition was tested with no short-circuit detected. The ATP was launched. There were no anomalies stated.

The unit was connected to the test bench. The NVM data were downloaded. There were 35 failure messages recorded, of which one is associated with the flight that ended up with the accident. The Table here below presents the features of this message.

Time[58]	Fault ID	Fault description	Comments
15:30:48	170	FIRE SW ACTION	The fire switch signal received by the GCU is seen active for 0.5s[59]

GCU #2 (right)

The unit was observed in a good external condition. The electrical condition was tested with no short-circuit detected. The ATP was launched. There were no anomalies revealed.

The unit was connected to the test bench. The NVM data were downloaded. There were 37 failure messages recorded, of which two are associated with the flight that ended up with the accident. The Table here below presents the features of these messages.

Time	Fault ID	Fault description	Comments
15:30:54	170	FIRE SW ACTION	The fire switchlight signal received by the GCU is seen active for 0.5s.
15:31:06	059	EEC 429 BUS	Loss of engine speed information for at least 30 s but with engine still running.

GAPCU

The traces of the thermal effect were observed on the unit. It was opened. The casing and the internal boards were covered with soot. The memory board was removed and cleaned by the isopropyl alcohol. It was decided to install it in the golden unit, not to allow the NVM data alteration.

The golden unit was connected to the test bench. The NVM was downloaded. There were 64 failure messages. There were no messages detected, related to the flight that ended up with the accident.

The memory board was again installed in the GAPCU, dismantled from the aircraft, involved in the accident. The ATP was launched that revealed no anomalies.

[58] The accuracy (sampling rate) of the timestamp record is 6 sec.
[59] This signal «passes» at the pressing (activation) of the ENG FIRE switchlight by the crew (to the engine fire protection system).

1.16.7. The examination of the VHF data radios/VDR, VHF

The examination was held at the facilities of the equipment designer - Thales (Brive- la- Gaillarde, France) in presence of the IAC and BEA representatives.

VDR1

The visual inspection did not reveal any damage. The traces of the fire extinguishing agent were observed on the fasteners. No visual defects were observed after the case was opened either.

The attempt to download the NVM turned out to be unsuccessful.

The original memory board was unsoldered, the new one was installed on its place afterwards. Then a number of tests was launched. The equipment failed the reception, transmission and VSWR operational manual tests. As these tests were a failure the automatic ATP test was not taken.

The memory board data readout was carried out at the BEA laboratory. The data were successfully downloaded. The analysis was the evidence that there are two messages, associated with the flight that ended up with the accident.

At 15:08 the message was recorded, indicating the disruption of the VDR reception and transmission functions. The further examination, carried out by Thales, revealed the traces of the antenna exposure to the lightning and melting of two PCB tracks inside the unit. The damage in question results in the disruption of the transmission/reception function.

The second message was recorded at 15:31 through the equipment power off.

VDR2 and VDR3

By results of the examination both radios were stated serviceable.

1.16.8. The examination of the Fuel System Control Unit/FSCU and Fuel Quantity Indication Computer/FQIC

The examination was carried out at the Safran Aerosystems (former Zodiac Aerotechnics) Repair Station in Plaisir, France, attended by the IAC and BEA representatives.

FSCU continuously monitors the operation of the aircraft fuel system pumps and valves. When the anomalies are detected FSCU sends the respective message to FQIC, where it is recorded. FSCU integrates its own NVM, but it does not contain any information, useful to the subject investigation.

FQIC calculates the fuel quantity in each tank and delivers this information to the aircraft systems. FQIC is a dual channel computer. Each channel incorporates its own NVM. To the channel 1 NVM the occurrences (failures) are recorded, delivered by the FSCU channel 1. To the channel 2 NVM the occurrences (failures) are recorded, delivered by the FSCU channel 2.

FSCU

The visual inspection of the unit revealed that there are the traces of soot and fire extinguishing agent on it. The unit was opened, the internal boards had the traces of soot on them as well.

After the cleaning of some boards the unit was reassembled and subject to the ATP. No comments were stated.

FQIC

The visual inspection of the unit revealed that there are the traces of soot and fire extinguishing agent on it. The unit was opened, the internal boards had the traces of soot on them as well. The boards were removed. No mechanical damage to the electronic components was revealed.

The boards, integrating the channel 1 and channel 2 NVM, were successively installed in the golden unit. The recorded information was copied (three files by a channel).

The computer was reassembled and subject to the ATP test (excluding the elements that lead to the record over of the NVM). No comments were stated.

FQIC records the messages (failures) in two databases. The dual channel design acts for redundancy. Generally each channel is to contain identical messages.

The BITE database integrates the messages (failures) to the pumps and valves operation, recorded into the last flight (leg)[60] that had been still active at the point of the computer switch off. The failures are recorded given the confirmation rate, which is unique for each message.

The FAILURE HISTORY database integrates the messages (failures) over the last 64 legs. The messages are available after cutting off the unit. The leg number is incremented at every ground/air transition. There is no attribution of the time stamps.

As into the porpoising there were several short-time ground/air transitions, then it is impossible to certainly attribute the time to the leg. In this context it may be argued that the messages, recorded into the last leg, certainly pertain to the flight that ended up with the accident. With that it has not been possible to unambiguously identify whether the countdown of the «accident flight» started from the point of takeoff or from either of the bounces. In other words, it cannot be said with much confidence whether three previous legs, recorded by the unit, belong to the flight that ended up with the accident.

The messages out of these in the FAILURE HISTORY database, recorded the last that are certainly associated with the flight that ended up with the accident, as well as the messages out of the BITE database, are given here below.

The BITE database messages are identical on both channels and shown on Fig. 45.

[60] Hereinafter through this Section the leg term is applied to designate the flight, recorded by FQIC.

BITE Element Id
DC_PUMP_LH
DC_PUMP_RH
APU_SW
AC_SW1_LH
AC_SW2_LH
AC_SW1_RH
AC_SW2_RH
DC_SW_LH
DC_SW_RH
AC_CONT1_LH
AC_CONT1_RH
ECU_BUS

Fig. 45. The BITE database messages

The FAILURE HISTORY database messages are identical on both channels as well except for the ENG_SOV_LH message, which was only recorded on channel 1. The channel 1 messages are presented in the table here below.

The ENG_SOV_LH message occurrence was due to the fact that at the left engine running, a signal of the wing SOV closed condition is recorded.

FAILURE MSG in record CH1_Leg#N (Record 1750)	Document Item	Failure Logic	Confirmation time of the failure	Possible failed LRUs
DENSITOMETER_OWN	EDD_FQIC_068	DENSIMETER OR FQIC (See Figure 4)	45s	Densimeter or harness of FQIC
TEMPERATURE_SENSOR_LH3	EDD_FQIC_056	TEMPERATURE_SENSOR OR FQIC (See Figure 4)	90s	Densimeter or FCS or harness of FQIC
TEMPERATURE_SENSOR_RH3	EDD_FQIC_056	TEMPERATURE_SENSOR OR FQIC (See Figure 4)	90s	FCS or harness of FQIC
AC_PUMP1_LH	ERD204	IF LH_AC_MAIN_PUMP_CMD discrete input is asserted AND LH_AC_MAIN_PUMP_LOW_PRESS is asserted AND LH_AC_MAIN_PUMP_POWERED is set THEN ARINC discrete output "LH_MAIN_PUMP_FAILED" (LABEL 302 B21) shall be asserted ELSE ARINC discrete output "LH_MAIN_PUMP_FAILED" (LABEL 302 B21) shall be reset	0s	AC Pump or AC Pump Pressure Switch or harness or FSCU
ENG_SOV_LH	ERD084	IF [(L_ENG_ON_CH1 discrete input is asserted AND L_ENG_VLV_OPEN discrete input is not asserted) OR (L_ENG_OFF_CH1 discrete input is asserted AND L_ENG_VLV_CLOSED discrete input is not asserted)] After ENG_VLV_FAIL_CONF delay THEN ARINC discrete output "LH_ENG_SOV_FAULT" (LABEL 302 B11) shall be set ELSE ARINC discrete output "LH_ENG_SOV_FAULT" (LABEL 302 B11) shall be reset	10s	FSCU Harness Engine SOV
APU_SW	ERD216D	IF APU_LOW_PRESS discrete input is asserted AND APU_NORM_PRESS discrete input is asserted THEN ARINC discrete output "APU_SWITCH_FAILED" (LABEL 303 B25) shall be asserted ELSE ARINC discrete output "APU_SWITCH_FAILED" shall be reset	0s	APU pressure Switch or harness or FSCU
DC_PUMP_RH	ERD202	IF RH_ADDT_PUMP_CMD discrete input is asserted AND RH_ADDT_PUMP_LOW_PRESS is asserted AND RH_ADDT_PUMP_POWERED is set THEN ARINC discrete output "R_ADDT_PUMP_FAILED" (LABEL 302 B20) shall be asserted ELSE ARINC discrete output "R_ADDT_PUMP_FAILED" (LABEL 302 B20) shall be reset	0s	DC pump or DC pump pressure Switch or harness or FSCU
DC_PUMP_LH	ERD200	IF LH_ADDT_PUMP_CMD discrete input is asserted AND LH_ADDT_PUMP_LOW_PRESS is asserted AND LH_ADDT_PUMP_POWERED is set THEN ARINC discrete output "L_ADDT_PUMP_FAILED" (LABEL 302 B19) shall be asserted ELSE ARINC discrete output "L_ADDT_PUMP_FAILED" (LABEL 302 B19) shall be reset	0s	DC pump or DC pump pressure Switch or harness or FSCU
AC_CONT1_LH	ERD170	IF (LH_AC_MAIN_PUMP_CMD discrete input is reset AND LH_AC_MAIN_PUMP_POWERED is asserted for CONTACT_FAILED_CONF seconds) OR (LH_AC_MAIN_PUMP_CMD discrete input is asserted AND LH_AC_MAIN_PUMP_POWERED is reset after CONTACT_FAILED_CONF seconds) THEN ARINC discrete output "LH_AC_MAIN_PUMP_CONTACT_FAILED" (LABEL 303 B13) shall be set ELSE ARINC discrete output "LH_AC_MAIN_PUMP_CONTACT_FAILED" shall be reset	0s	AC pump or AC pump pressure Switch or harness or FSCU
DC_SW_RH	ERD180	IF (RH_ADDT_PUMP_NORMAL_PRESS discrete input is asserted AND RH_ADDT_PUMP_LOW_PRESS is asserted) OR (RH_ADDT_PUMP_NORMAL_PRESS discrete input is reset AND RH_ADDT_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "RH_ADDT_PUMP_SWITCH_FAILED" (LABEL 303 B18) shall be set ELSE ARINC discrete output "RH_ADDT_PUMP_SWITCH_FAILED" shall be reset	0s CONTACT_FAILED_CONF=1s	DC Pump Switch OR Harness OR FSCU

DC_SW_LH	ERD178	IF (LH_ADDT_PUMP_NORMAL_PRESS discrete input is asserted AND LH_ADDT_PUMP_LOW_PRESS is asserted) OR (LH_ADDT_PUMP_NORMAL_PRESS discrete input is reset AND LH_ADDT_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "LH_ADDT_PUMP_SWITCH_FAILED" (LABEL 303 B17) shall be set ELSE ARINC discrete output _ADDT_PUMP_SWITCH_FAILED" shall be reset	0s	DC Pump Switch OR Harness OR FSCU
AC_SW2_RH	ERD188	IF (RH_AC_AUX_PUMP_NORMAL_PRESS discrete input is asserted AND RH_AC_AUX_PUMP_LOW_PRESS is asserted) OR (RH_AC_AUX_PUMP_NORMAL_PRESS discrete input is reset AND RH_AC_AUX_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "RH_AC_AUX_PUMP_SWITCH_FAILED" (LABEL 303B22) shall be set ELSE ARINC discrete output "RH_AC_AUX_PUMP_SWITCH_FAILED" shall be reset	0s	AC Pump Switch OR Harness OR FSCU
AC_SW1_RH	ERD186	IF (RH_AC_MAIN_PUMP_NORMAL_PRESS discrete input is asserted AND RH_AC_MAIN_PUMP_LOW_PRESS is asserted) OR (RH_AC_MAIN_PUMP_NORMAL_PRESS discrete input is reset AND RH_AC_MAIN_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "RH_AC_MAIN_PUMP_SWITCH_FAILED" (LABEL 303 B21) shall be set ELSE ARINC discrete output "RH_AC_MAIN_PUMP_SWITCH_FAILED" shall be reset	0s	AC Pump Switch OR Harness OR FSCU
AC_SW2_LH	ERD184	IF (LH_AC_AUX_PUMP_NORMAL_PRESS discrete input is asserted AND LH_AC_AUX_PUMP_LOW_PRESS is asserted) OR (LH_AC_AUX_PUMP_NORMAL_PRESS discrete input is reset AND LH_AC_AUX_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "LH_AC_AUX_PUMP_SWITCH_FAILED" (LABEL 303 B20) shall be set ELSE ARINC discrete output "LH_AC_AUX_PUMP_SWITCH_FAILED" shall be reset	0s	AC Pump Switch OR Harness OR FSCU
AC_SW1_LH	ERD182	IF (LH_AC_MAIN_PUMP_NORMAL_PRESS discrete input is asserted AND LH_AC_MAIN_PUMP_LOW_PRESS is asserted) OR (LH_AC_MAIN_PUMP_NORMAL_PRESS discrete input is reset AND LH_AC_MAIN_PUMP_LOW_PRESS is reset) THEN ARINC discrete output "LH_AC_MAIN_PUMP_SWITCH_FAILED" (LABEL 303 B19) shall be set ELSE ARINC discrete output "LH_AC_MAIN_PUMP_SWITCH_FAILED" shall be reset	0s	AC Pump Switch OR Harness OR FSCU
AC_CONT1_RH		IF (RH_AC_MAIN_PUMP_CMD discrete input is reset AND RH_AC_MAIN_PUMP_POWERED is asserted for CONTACT_FAILED_CONF seconds) OR (RH_AC_MAIN_PUMP_CMD discrete input is asserted AND RH_AC_MAIN_PUMP_POWERED is reset after CONTACT_FAILED_CONF seconds) THEN ARINC discrete output "RH_AC_MAIN_PUMP_CONTACT_FAILED" (LABEL 303 B15) shall be set ELSE ARINC discrete output "RH_AC_MAIN_PUMP_CONTACT_FAILED" shall be reset	0s CONTACT_FAILED_CONF =1s	AC Pump OR AC Pump Switch OR Harness OR FSCU
LH_FADEC_BUS		IF The LH FADEC bus is flagged FAILED THEN The ARINC label 247 « TOTAL_FUEL_REMAINING » shall be sent with the SSM set to NCD AND The ARINC label 213 « L_ENG_FUEL_USED » shall be sent with the SSM set to NCD AND The ARINC label 244 « TOTAL_AC_FUEL_USED » shall be sent with the SSM set to NCD AND The ARINC label 276 « LH_FADEC_BUS_FAILED » bit 17 shall be set	0s	FADEC Or Harness Or FQIC.

1.16.9. The examination of the fuel system SOV twin motor actuators

The examination was held at the facilities of Safran Aerosystems (former Zodiac Aerotechnics) equipment manufacturer (Roche-la-Molière, France), attended by the IAC and BEA representatives.

The twin motor actuator is an electromechanical assembly. Fig. 46 presents the schematic of the actuator. The twin motor actuators control the SOV and are installed at the fuel systems locations as follows:

- 1 SOV on the refuel left wing tank,
- 1 SOV on the refuel right wing tank,
- 1 SOV on the central tank,
- 1 SOV on the left engine feed line,
- 1 SOV on the right engine feed line,
- 1 SOV on the crossfeed line,
- 1 SOV on the APU feed line.

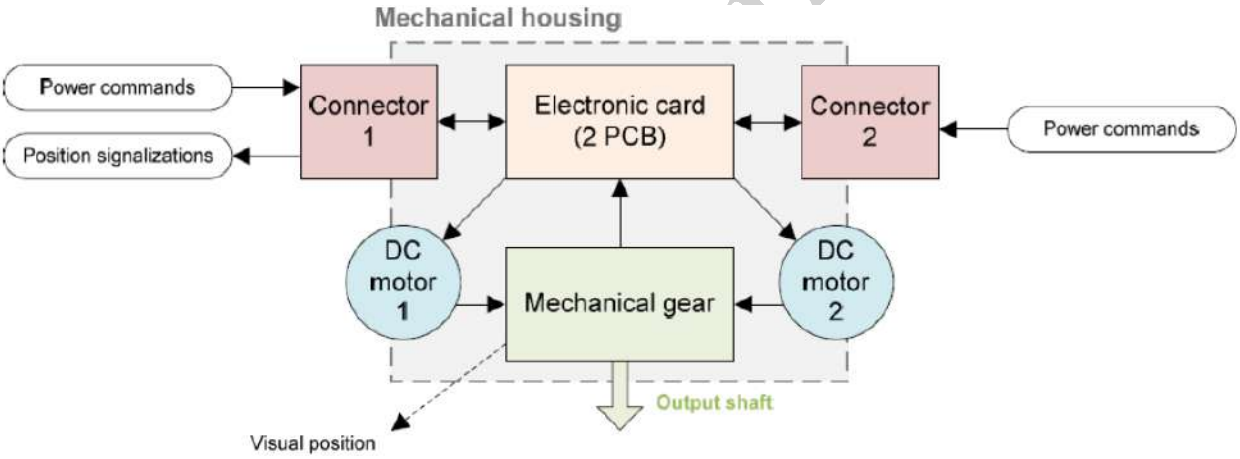


Fig. 46. The schematic of the twin motor actuator

At the power off the actuators remain positioned as they were at the point of this power off.

Within the subject examination two actuators were assessed, installed on the fuel valves in the left and right engine feed lines.

Twin motor actuator 1

At the visual inspection it was identified that the actuator sustained substantial high temperature damage. The actuator was observed in the opened position (condition).

The impedances of the connector were tested to confirm the position and to know if the actuator could go through the ATP. It was found in open position with short circuits.

It was decided to open the actuator. After it was opened its opened position was confirmed. The short circuits were caused by plastic parts inside the two DC motors. These parts were deformed, affected by high temperatures. On the borders of these plastic parts there were two contacts in metal. Because of the deformation the contacts contacted the casing in metal as well. It was decided to replace the two damaged pieces and run the ATP. Once the parts were replaced, two impedance values were stated being off the specification, but the entire performance test was in conformity.

Twin motor actuator 2

At the visual inspection the actuator was stated being in a good condition. The actuator was found in the open position (condition). The impedances of the connector were tested to confirm the position and to know if the actuator could go through the ATP. The open position of the actuator was confirmed, the electrical parameters meet the specification. The ATP was run successfully without comments.

1.16.10. The examination of the left sidestick, the Primary Flight Control Units/PFCU, the Actuator Control Electronics/ACE and the Motor Actuator Control Electronics/MACE

Three FCS PFCU computers ensure the FCS interface with the other aircraft systems to exercise the NORMAL MODE functions.

Fourteen ACE units of two types (ACE I, 8 units and ACE II, 6 units) enable:

- the transmission of signals from the flight controls sensors to the PFCU and the control of the actuators by the PFCU signals;
- the direct actuator control by the signals from the flight controls sensors in DIRECT MODE.

Each ACE unit integrates the control channel and the monitor channel. The ACE control channel enables the control of the repositioning of the aerodynamic surfaces. The monitor channel monitors the control channel operation and at the onset and detection of failure reverts the system in the failsafe operational mode. The PFCU computers and the ACE units are interconnected and installed in the left and right cabinets.

Six Motor Actuator Control Electronics/MACE enable:

- the control of the electric actuators by the flight controls signals together with the PFCUs;
- the direct actuator control by the flight controls signals in DIRECT MODE.

Each MACE controller integrates the control, the monitor, and the actuator control (of the electric motor and power electronics) channels.

The MACE controllers control the electric motors operation that actuate the flaps/slats ballscrew drives and stab trim mechanisms.

In the «auto trim» mode the stabilizer MACE controllers receive the control commands from the PFCU computers.

The monitor channels monitor the operation of the control channels and at the onset and detection of failure revert the system to the failsafe operational mode.

The examination was carried out in two stages.

At the first stage at the IAC laboratory in presence of the SCAC, JSC and Liebherr-Aerospace GmbH experts the visual inspection was carried out with the readout of the data out of 14 ACEs and 3 PFCUs. All the units were stated serviceable, the failure dump was successfully downloaded from all the units.

As all the MACE units showed the traces of the high temperature effect and fire extinguishing agent on them it was decided to arrange their examination at the manufacturer facilities (Liebherr-Aerospace GmbH, Lindenberg, Germany) with the participation of the IAC and BFU representatives.

Each MACE records the occurrences by the channels: these of the control, monitoring and actuator control. After the units were subject to teardown and installed in the golden units the download of the data was performed. The data to all the units were successfully downloaded by the monitor and motor control channels. The memory dumps by the control channel to all the units were empty. The additional examination was the evidence that the download was not performed due to the error in the test bench software. The absence of these control channels did not anyhow affect the analysis and examination findings, as the data are are available on the other channels as well.

The analysis of the downloaded data to the PFCU, ACE and MACE revealed that prior to the aircraft exposure to the atmospheric electricity the FCS had operated in NORMAL MODE.

Starting from 15:08:11 a number of failures is recorded. Among these, at 15:08:12 all three PFCU detected no sign of the ADC/air data computer data validity, delivered by the EIUs 1 and 2. The loss of the validity sign occurred due to no update of the data, delivered by the EIUs. This failure confirmation time is 500 msec.

At the occurrence of this failure fully in line with the design-integrated logic:

- all three PFCUs reverted in the minimum mode (DIRECT MODE);
- all three PFCUs «commanded» the reversion to minimum mode (DIRECT MODE) to all the ACE and MACE units;
- all three PFCUs received confirmation by all ACE and MACE units on their reversion to the minimum mode (DIRECT MODE).

Hence, all the ACE (ALHIB, ALHOB, ARHIB, ARHOB, ELHIB, ELHOB, ERHIB, ERHOB, RUPP, RCEN, RLOW, SPO 1, 2, 3) and MACE (SSM1 (RH), SSM2 (LH), Flap1 (LH), Flap2 (RH), Slat1 (LH), Slat2 (RH)) units reverted to the minimum mode (DIRECT MODE) as assigned.

Into the further flight the system normally operated in the minimum mode (DIRECT MODE), including the record of three touchdowns at the aircraft landing. After the third touchdown a number of failures was recorded, associated with the damage to the aircraft structural elements and the exposure to fire.

Starting from 15:30:58 a number of occurrences is recorded, indicating the aircraft AC power off.

The last occurrence is recorded at 15:31:09, after which it probably was the total power off of the units.

The examination of the left sidestick was carried out at the manufacturer facilities (Liebherr-Aerospace GmbH, Lindenberg, Germany), attended by the IAC and BFU experts. There were no comments stated on the serviceability.

It was stated apart that:

- the sidestick priority pushbutton was observed in a serviceable condition;
- the sidestick functional check on the test bench did not reveal any anomalies. Inter alia, no malfunction was identified, implying the sensation of the «sluggish» («lagged») sidestick, which the pilot was complaining of.

The test bench allows simulating the response (deflection) of the control rods (control surfaces) to the sidestick deflection. Fig. 47 shows the schematic of test bench. The bench incorporates the material sidesticks and the electronic units (PFCU and ACE), the actuators operation is simulated in real time on the basis of the certified engineering model, updated by the results of the flight tests.

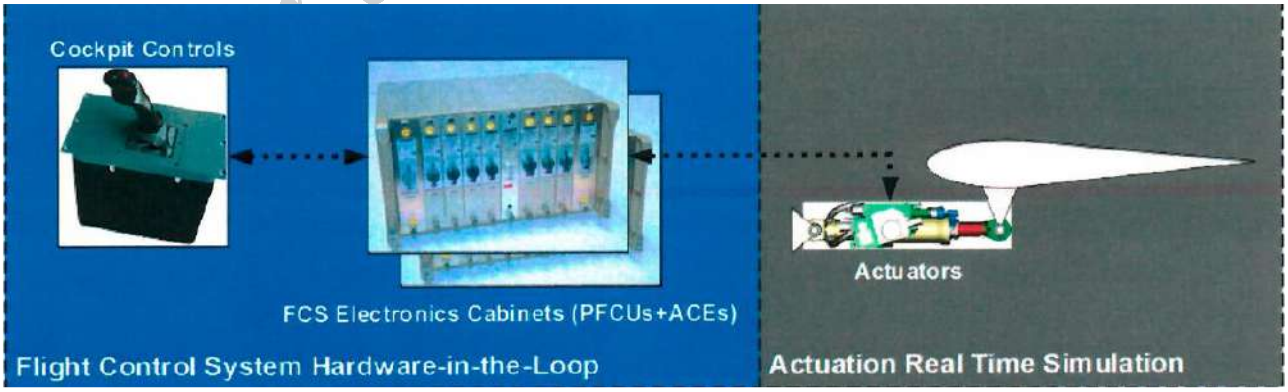


Fig. 47. The schematic of the test bench to look at the sidestick

As the outcome of the checks on the test bench the graphs of the sidestick deflection in pitch and roll were plotted (Fig. 48 and Fig. 49), as well as the associated actuators (control surfaces) response in the open-loop system (without the airplane) and at the operation of the FCS in the minimum mode (DIRECT MODE).

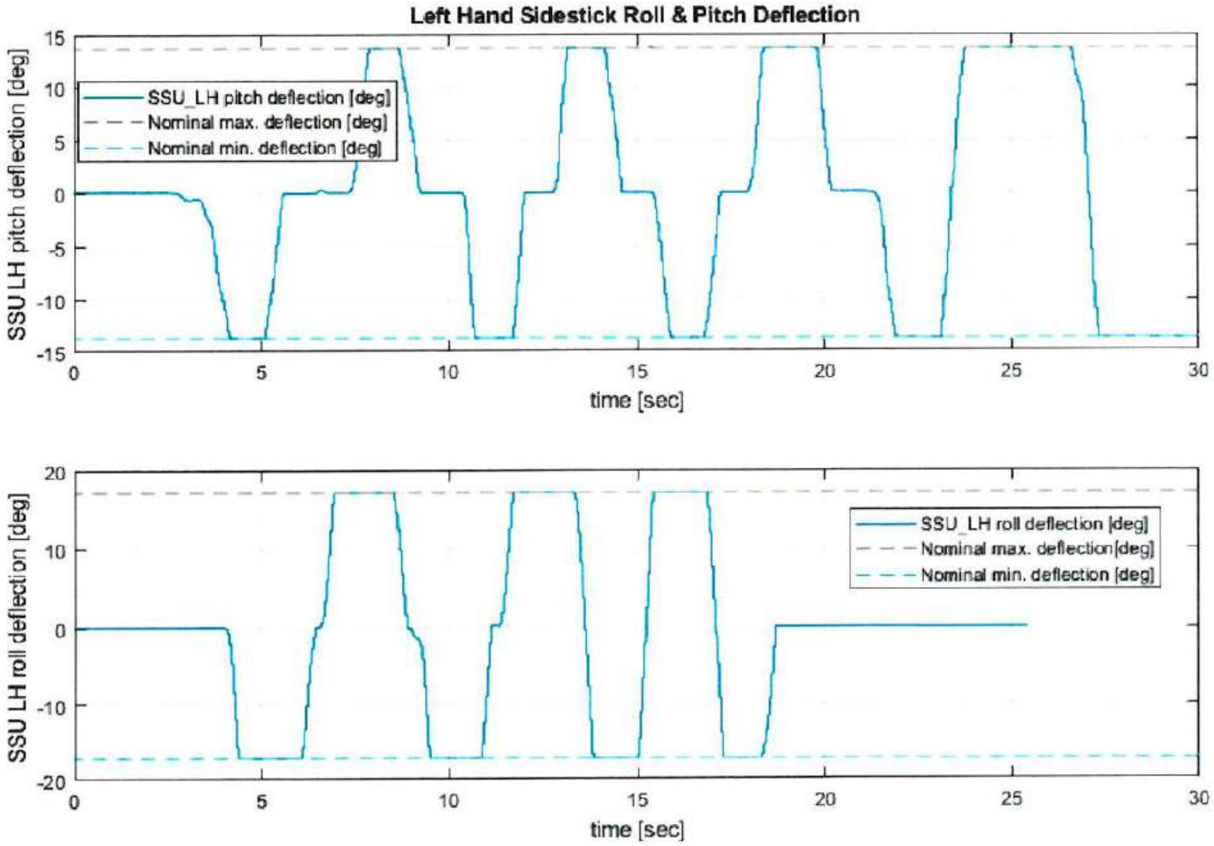


Fig. 48. The test of the left sidestick deflection range in roll and pitch

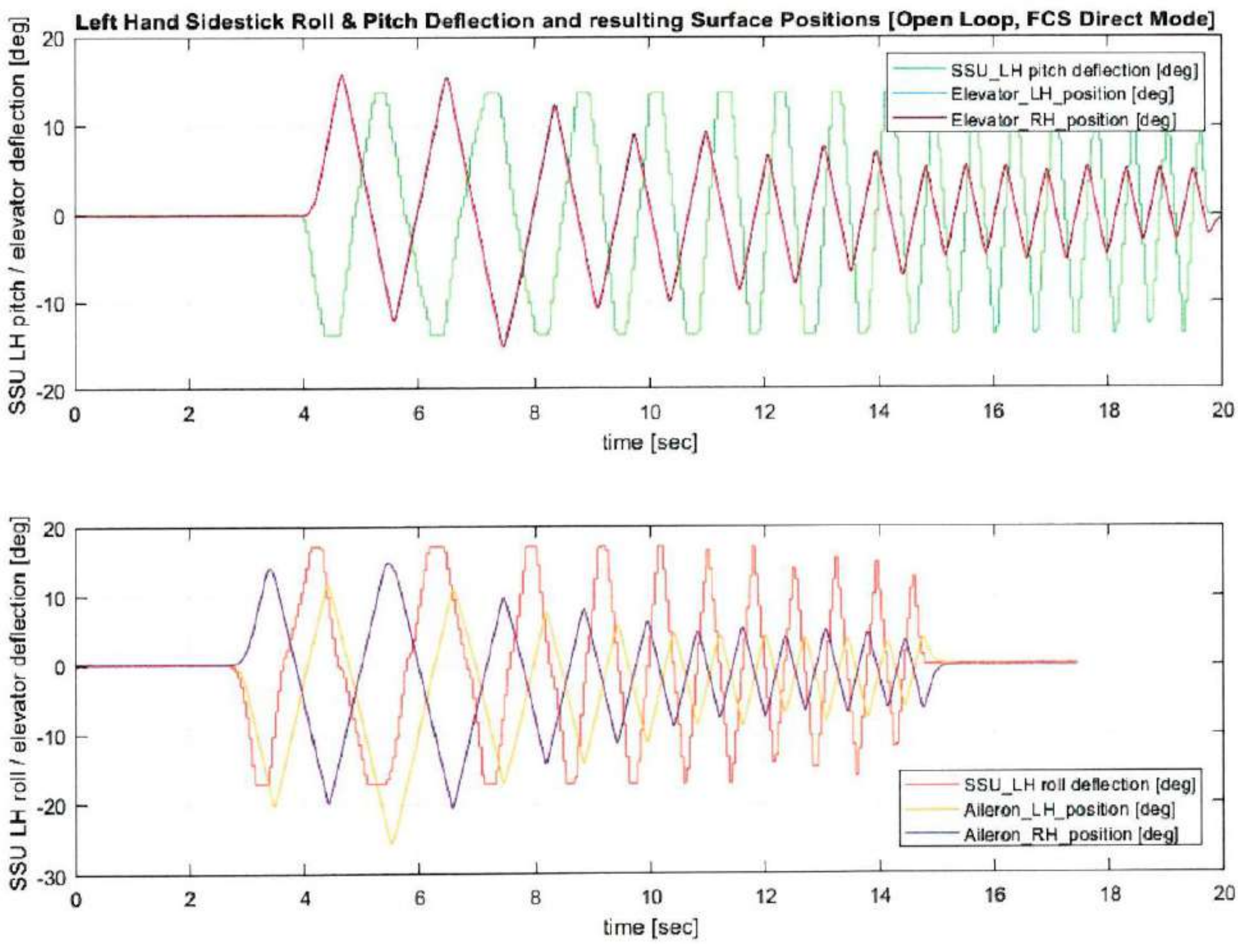


Fig. 49. The simulation of the response (deflection) of the actuator rods to the sidestick deflection

The plots show in particular that:

- the maximum available deflection of the sidestick in roll and pitch is in line with the specification;
- at the rapid sidestick deflection against the stops with keeping it retained the repositioning rate of the control rod (control surface) is constant and determined by the actuator performance, i.e. the control rod (control surface) is repositioned against the stop with the lag relative to the sidestick deflection. This lag is the greater, the more is the sidestick deflection rate;
- if the time of the sidestick keeping retained in the limit position is relatively short, then due to the limited available rate of the control rod repositioning the control surfaces do not have time to reach their limit positions. The actual maximum reached magnitude of the control rod (control surface) deflection against its available (maximum) repositioning rate depends on the time of the sidestick keeping retained at the stop and the magnitude of the previous deflection in the opposite direction.

1.16.11. The examination of the NVM to the aircraft weather radar processor

The MAK-IAC and SCAC experts had carried out the readout of the NVM data to the aircraft weather radar processor. The data readout had been arranged, compliant to the manufacturer procedure (Honeywell, USA). The decoding and analysis of the read out data had been carried out in collaboration with NTSB and Honeywell.

As the follow-up to the performed works there had been no comments stated on the weather radar serviceability and efficiency. It had been determined that into the flight that ended up with the accident one PREDICTIVE WINDSHEAR event of the WARNING type had been recorded, having been accompanied by the GO AROUND, WINDSHEAR AHEAD synthetic voice. The indicated message had been recorded at 15:28:18, when the airplane had been flown on the landing heading at the true altitude of about 1100 ft. (335 m).

1.16.12. The examination of the aircraft and ground weather radars indications correlation

As stated in the previous section there had been no anomalies revealed in the operation of the aircraft weather radar into the flight that ended up with the accident. Nevertheless it has not been possible to replicate the aircraft weather radar indications at the flight that ended up with the accident. At that the investigation team had been submitted the data (indications) of the Vnukovo TDWR.

The subject of this examination had been the comparative analysis of the RDR-4000 aircraft weather radar and the Vnukovo TDWR indications.

The activities had been held on June 5, 2020 aboard the RRJ-95B airplane, MSN 95005 at the facilities of the Irkut Corporation Regional Aircraft branch Flight Test Complex at Ramenskoye aerodrome (the town of Zhukovsky) over a period of time of 12:00 - 13:00 (15:00 - 16:00 MSK).

The airplane had been allocated at the Regional Aircraft branch Flight Test Complex site with the magnetic heading of 192° (the true heading of 203°). The airplane had been powered from the ground power source. In the progress of the performed checks the weather radar:

– had functioned as assigned, performing the preset functions into the operational modes («AUTO» and «MAN»);

– had ensured the information acquisition and the display of the data on the weather formations of different intensity (including the hazardous ones) at the ND (MFD) towards the front hemisphere ahead of the aircraft;

– had ensured the detection of the attitude and distance to the observed weather formations;

– had ensured the control of the weather radar receiver sensitivity with the use of the GAIN control knob.

The knobs on the weather radar control panel had been positioned as follows:

- TEST / NORM in the NORM position;
- MAP / AUTO / MAN in the AUTO position;
- GAIN in the middle (upper) CAL position.

By pressing the WXR / TERR pushbutton at the left FCP the main mode of the weather data display had been selected at the PIC's ND. With the RANGE knob at the PIC's ND the weather formations display in a scale of 20 nm had been selected. The map display mode at the PIC's ND had been the ARC one.

Further on the weather radar had been turned on to the transmission mode by pressing the WXR ON / OFF pushbutton on the left overhead panel. At the PIC's ND the image of the weather formations had been generated, as shown on Fig. 50. The aircraft weather radar indication as of 12:26 on June 5, 2020, the GAIN knob is in the CAL position.

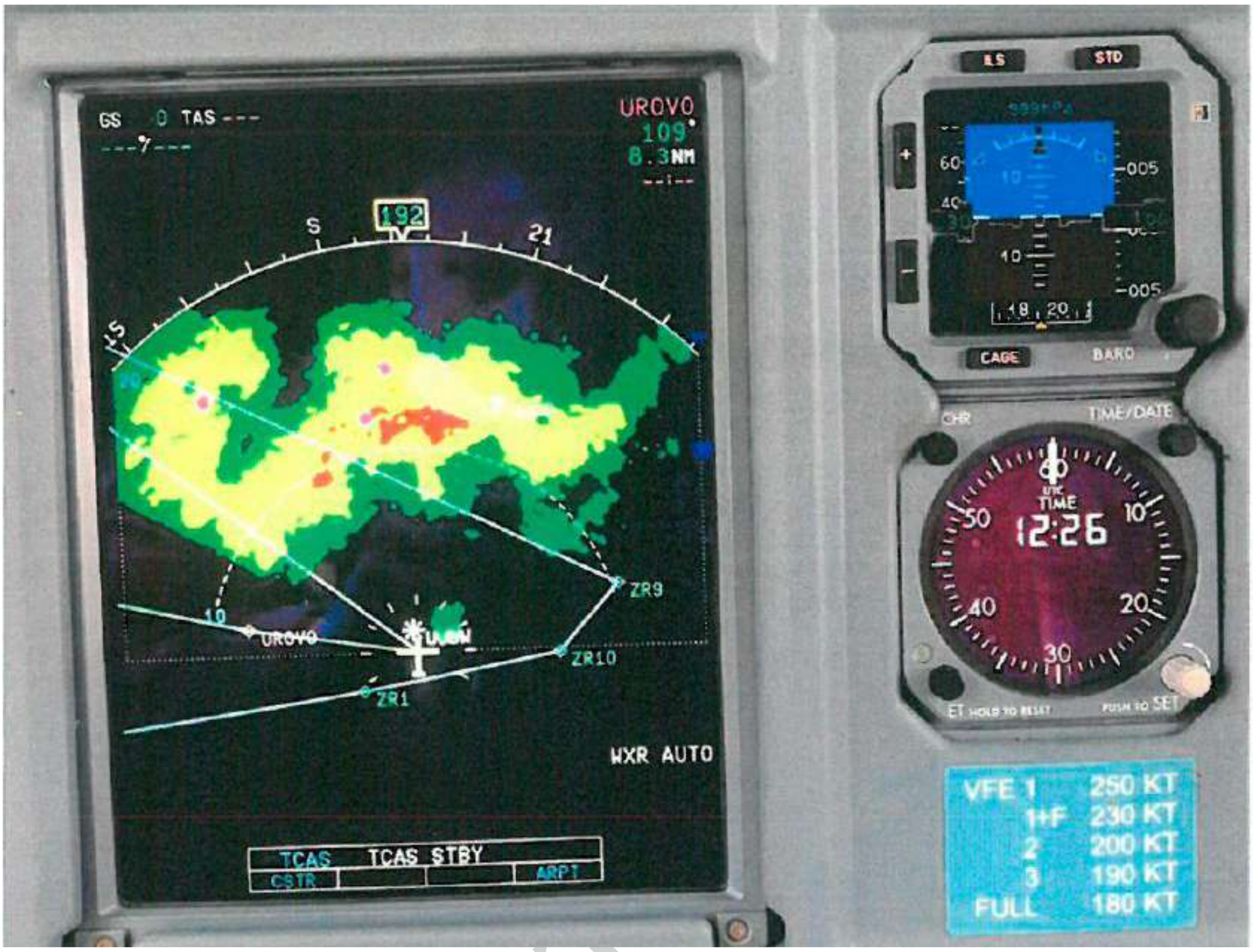


Fig. 50. The aircraft weather radar indication as of 12:26 on June 5, 2020, the GAIN knob is in the CAL position

The weather formations areas are displayed at the ND, depending on the intensity of the reflected signals as per the following levels.

The level of weather formations	Returns	The rainfall rate, mm/h	Reflectivity (signal dB/km)	The color of the weather formations at the ND
0	Very light	Less than 0.7	Less than 20	Black
1	Light	0.7 - 4.1	20 - 30	Green
2	Medium	4.1 - 11.94	30 - 40	Yellow
3	Strong	11.94 - 51	40 - 50	Red
4	Very strong	Greater than 51	Greater than 50	Red
-	Turbulence	-	-	Magenta

The indicated image had been compared with the data, obtained from the Vnukovo TDWR of 12:30 (Fig. 51).

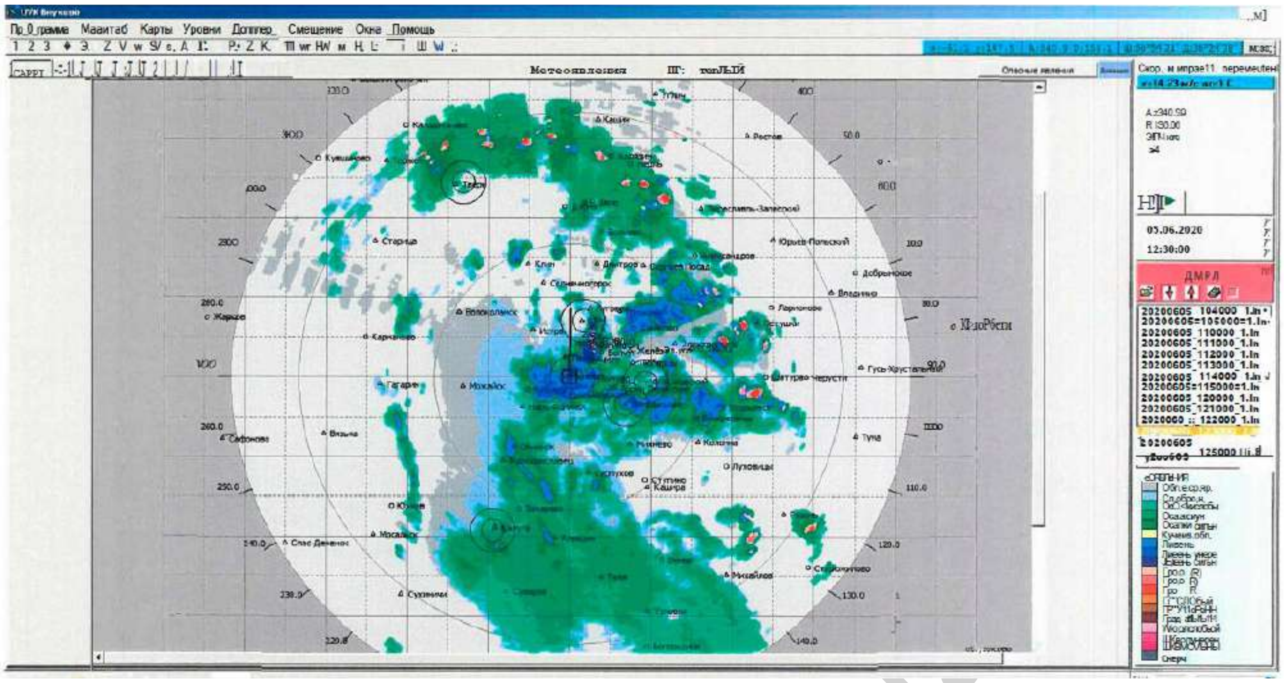


Fig. 51. The Vnukovo TDWR indication as of 12:25-12:30 on June 5, 2020

The result of matching of two indicated images is as follows (Fig. 52).

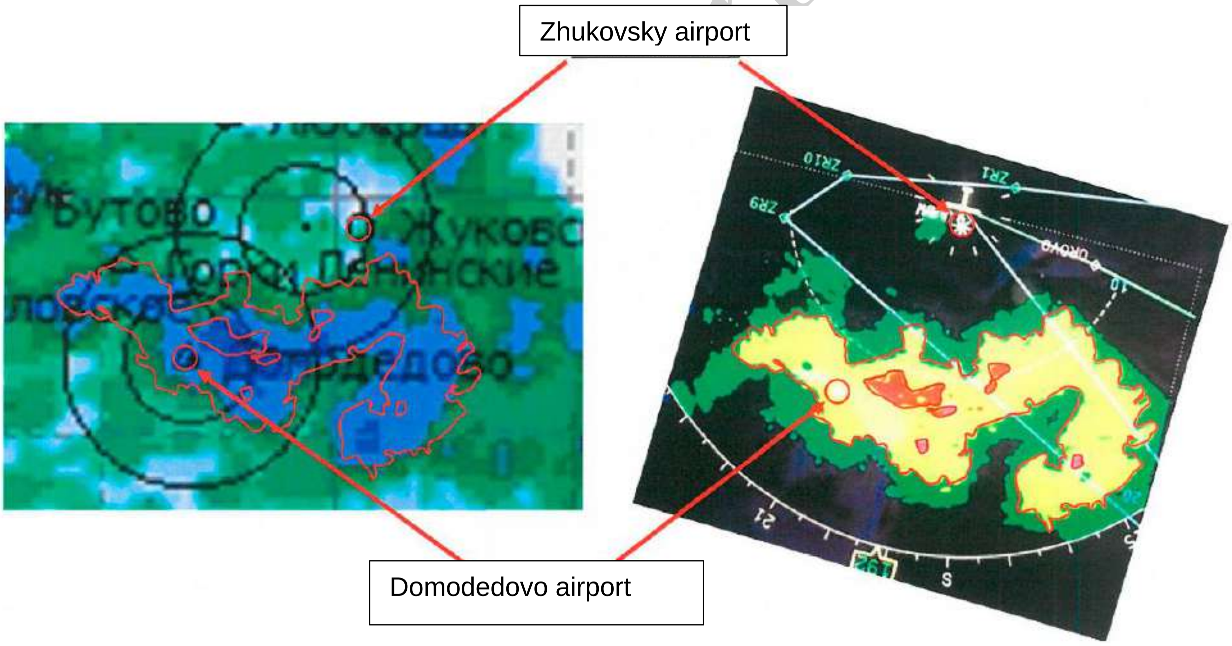


Fig. 52. The matching of the data by the aircraft weather radar and the Vnukovo TDWR

Both images are introduced in one north-facing coordinate system and brought to one scale by comparing the reference points location that are present on both images – these are Zhukovsky and Domodedovo airports.

After bringing to the single scale and orientation the areas of hazardous weather formations from the aircraft weather radar had been plotted on the Vnukovo TDWR image, corresponding to the colors of yellow and red.

The comparison of the nature of the weather formations display out of the Vnukovo TDWR and this by the aircraft weather radar had been the evidence that the areas of the weather formations of the Vnukovo TDWR, attributed to the strong rainfall, light and moderate shower rain are visually similar with the areas of weather formations out of the RRJ-95 aircraft weather radar, as such: of the green, yellow and red color. The comparison of the color coding as per the rainfall rate is given on Fig. 53.

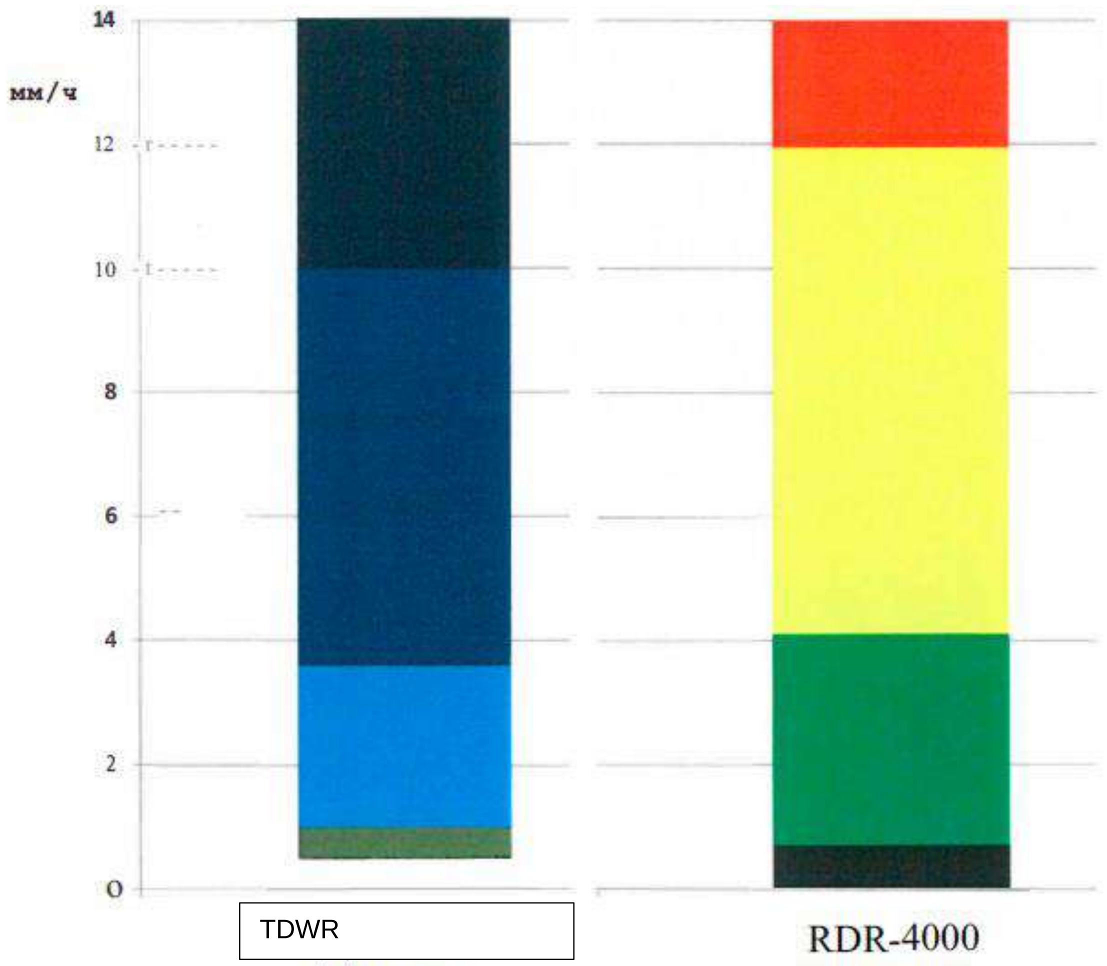


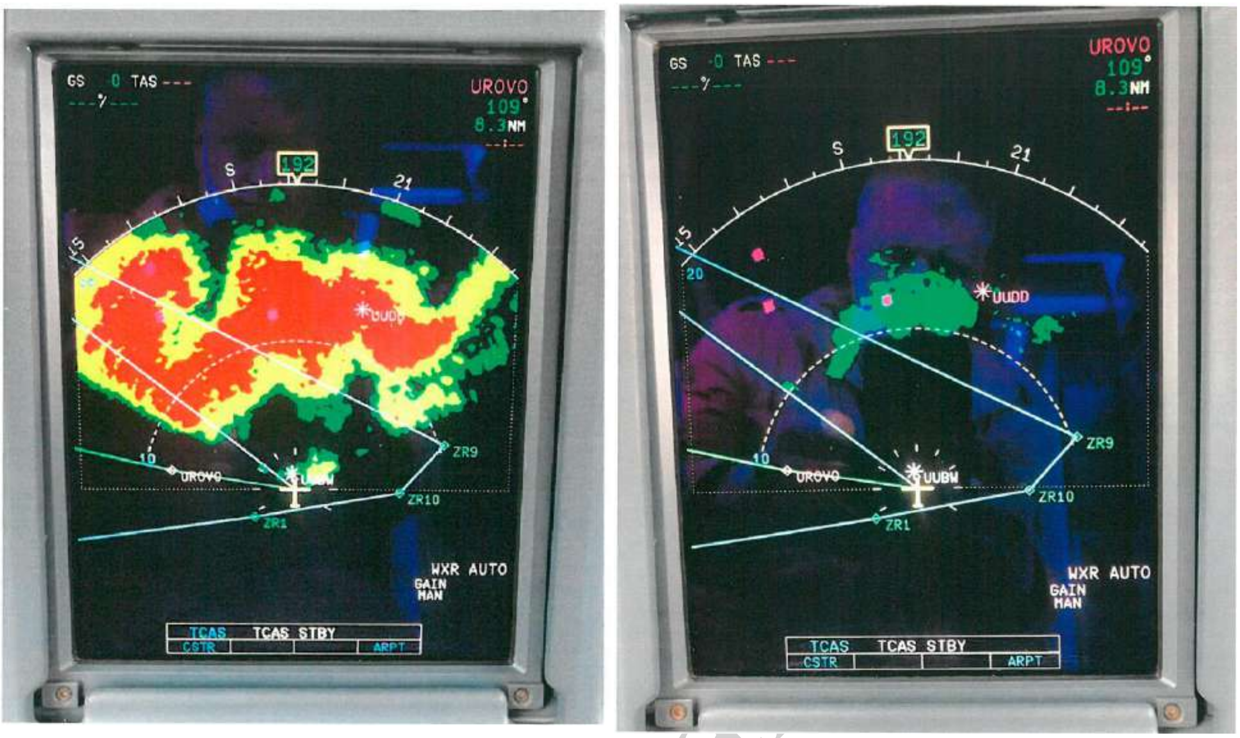
Fig. 53. The comparison of the color coding to the aircraft weather radar and the Vnukovo TDWR

The comparative analysis allows to conclude that the aircraft weather radar evaluates the precipitation as no less intense, compared with the Vnukovo TDWR. That is to say the aircraft weather radar is more conservative and alerts the crew with the margin (earlier) on the hazardous weather.

Fig. 54 presents the images of the weather environment at the GAIN knob in the MAX and MIN positions. The generated images are significantly different of that, obtained at the knob in the CAL position (Fig. 50).

Note: ***FCOM 2.34.70 p. 4***

At the GAIN knob setting to the position, other than CAL, GAIN MAN is displayed on the ND. Changing the sensitivity does not affect the detection of turbulence *and windshear. Upon evaluating the weather environment set the GAIN knob to the CAL position.*



the GAIN knob in the MAX position **the GAIN knob in the MIN position**

Fig. 54. The aircraft weather radar indication as of 12:26 on June 5, 2020

1.16.13. The examination of the aircraft MLG legs attachment A fuse pins («weak links»)

At the request by the investigation team the pins material properties had been subject to the examination at the All-Russian Research Institute for Aviation Materials, FSUE to denote the nature of destruction of the aircraft MLG legs attachment A fuse pins («weak links»).

On the follow-up of the performed examination the pins compliance to the documentation requirements in terms of the material properties had been validated. It had been determined that the destruction had occurred in line with the parameters, having been integrated at the design of the «weak link», at the one-time application of the destructive load.

1.16.14. The examination of the right engine High Pressure Shut-Off Valve/HPSOV

By the method, provided by PowerJet the IAC and SCAC, JSC experts carried out the examination of the High Pressure Shut-Off Valve/HPSOV to the right engine. The HPSOV was observed in the closed position.

Note: *The HPSOV has a spring to maintain the valve closed when the engine is shut down. For example, at the engine startup, when the crew switches ENG MASTER to the ON position, the opening does not occur immediately. The HPSOV is opened by fuel pressure, which depends on the engine rotational speed (N_2 ~ 10%).*

1.16.15. The examination of the Fire Protection Computer/FPC

By the investigation team request the examination of the Fire Protection Computer/FPC was held at the Curtiss-Wright manufacturer facilities (Santa Clarita, USA).

On July 3, 2019 the FPC was shipped to NTSB (USA). From the point the computer was delivered to the addressee (July 22, 2019) the process was initiated of the coordination of the investigation team representatives' visit to USA to attend the examination. Owing to the substantial delay in the issuance of the USA entry visas it has not been possible to promptly arrange the examination.

Later on due to the imposition of the lockdown restrictions, associated with COVID-19, both in the Russian Federation and USA, it did not prove possible to arrange the investigation team representatives' visit to USA.

On March 18, 2020 due to the persisting difficulties the investigation team made the decision that the subject examination be carried out by the Curtiss-Wright experts, supervised by NTSB without the participation of the investigation team representatives with the thorough documenting of the process and further submission of the report on the accomplished works. The start of the activities on the teardown and examination of the computer was further postponed several times due to the measures taken by the US Government and individual US entities to restrict mobility of the enterprises and entities employees in a pandemic.

Once the pandemic situation improved in USA, the representatives of Curtiss-Wright notified NTSB that the test bench was out of order that resulted in another postponement of the works. Once the normal operation of the test bench was resumed the plan and timing of the examination were agreed on.

The examination of the FPC (s/n 3793292) was held on August 12, 2021 under the supervision of the NTSB representative.

As per the submitted report of September 29, 2021 the FPC was stated in a good condition, it successfully ran the ATP. There were no signs detected of its non-serviceability. They arranged as well the download of the data out of the FPC NVM.

Three types of data are recorded in the NVM:

- the failures (messages), recorded in the course of the Power-Up Test;
- the failures (messages), obtained by the computer in-flight (Continuous Test);
- the time, elapsed since the last power-up.

At the record of the messages (failures) their UTC time stamping is not enabled.

The downloaded information was decoded by the Curtiss-Wright experts. According to their statement, the Continuous Test section did not contain any messages (failures). The Power-Up Test section integrates two identical entries on the failures, associated with the loss of the DC

+15 volts signal. At the last powering of the computer it was electrically charged for less than 60 sec. The information in question indicates that at the last stage the computer power supply was disrupted.

Along with that the Curtiss-Wright representatives refused to provide the investigation team with the detailed results of the decoding of the data, downloaded out of the NVM, substantiating it with the fact that this information is subject to the company intellectual ownership. For the similar reason the Curtiss-Wright experts refused to respond the additional questions by the investigation team, forwarded in the letter of October 8, 2012 to NTSB and redirected to Curtiss-Wright afterwards.

1.16.16. The examination of the consistency of the RRJ-95 aircraft FFS engineering model with the flight tests records and the records of the RRJ-95B RA-89098 aircraft motion dynamics into the flight that ended up with the accident

The examination had been carried out by the group of experts out of IAC, FATA, Aeroflot, PJSC and SCAC at the FFS, installed at the Aeroflot, PJSC Air Training Center.

Two tasks had been solved in the progress of the examination:

- to demonstrate the earlier determined compliance of the RRJ-95B FFS engineering model with the type aircraft performance (the records, obtained at the flight tests);
- to replay at the FFS the RRJ-95B RA-89098 motion dynamics into the flight of May 5, 2019 that ended up with the accident.

The assessment of compliance of the RRJ-95B FFS engineering model had been carried out by conducting the tests, specified in the Technical Specification as per the Qualification Test Guide/QTG.

On the simulators of the Reality Seven family, manufactured by L-3 CTS, all the QTG manual or automatic tests are carried out with the use of the Windows Autotest Generation System/WAGS built-in special software, delivered by the manufacturer as a part of the simulator. In a manual mode the vector of the input control parameters is generated in proceeding the aircraft manual control. In automatic mode the vector of the input control parameters is read out of the custom file. In the examination in question to eliminate the human factor effect only the automatic mode of the data input had been used.

WAGS is a set of the software tools to perform, record the results and generate the reports with the results of QTG qualification tests. Requirements to the file components for the test, descriptions of the WAGS tools for arranging test files are presented in the FFS Technical Publications in the SOLiD – Interactive Electronic Technical Manual Document Reference 70 004

037-194 Rev E dated 08/03/2016 (hereinafter referred to as EDF) / Simulator Support /SOFTWARE USER GUIDES/WAGS Section.

The vector of the output parameters of the simulation result at the FFS is automatically compared to the vector of the output parameters, obtained in the progress of the prototype airplane test flight. For the RRJ-95B aircraft FFS the data of the flight tests are used of the RRJ-95B aircraft MSN 95001, 95003, 95004 and 95005.

To ensure the entry qualification of the Reality Seven family FFS, with the use of the built- in WAGS tools for each test, test files are arranged in a special format out of the package of initial flight test data (field or bench ones), containing an array of input (control) and output reference parameter values. The test files integrate as well the initial conditions and trim values, required to run the tests.

All the information on the initial data to the QTG, the airplane MSN and configuration, the date and number of flight, the time interval to the record of the flight in use into the test are shown in the VDR (Validation Data Roadmap) stand-alone document, which is an integral part of the Master QTG package. The test files are stored on the computer, being a part of the simulator processing complex.

According to the results of testing by the described method the compliance had been confirmed. The results of the accomplished tests confirm the convergence of the simulator engineering model with the records of the flight tests.

Note: *For tests at the demonstration of compliance of the motion dynamics near the ground under the ground effect the elevator deflection angles insignificant exceedance is observed beyond the acceptable limits. The description of the exceedance of the kind is stated in the Test Data Information/Rationale for SSJ100 FULL FLIGHT SIMULATOR QTG REV. D document, approved by EASA and FATA. The exceedance of the elevator surfaces beyond the acceptable limits is explained by the oscillations at the damping of atmospheric disturbances, which cannot be replayed into the motion model.*

To assess the compliance of the simulator engineering model with the records of the RA-89098 airplane motion dynamics into the flight of May 5, 2019 that ended up with the accident, SCAC Technical Training Aids Scientific-Research Department, based on the RA-89098 airplane FDR data, had arranged the following test modes.

#	The WAGS test title	Test	The FBWCS operational mode	The time interval as per the FDR record

<table>
<tr><td>1</td><td>Line</td><td>Cruise flight</td><td rowspan="4">DIRECT MODE</td><td>between
15:27:13 - 15:27:46</td></tr>
<tr><td>2</td><td>Turn</td><td>Turn</td><td>between
15:12:43 - 15:13:25</td></tr>
<tr><td>3</td><td>Appr</td><td>Descent</td><td>between
15:27:39 - 15:28:12</td></tr>
<tr><td>4</td><td>Target</td><td>The glideslope flight
till the first touchdown</td><td>between
15:29:47 - 15:30:02</td></tr>
</table>

The test files to demonstrate the compliance had been arranged by the State Research Institute for Aviation Systems, FSUE by the standard procedure to perform QTG, based on the selection of the flight path segments, arranged at the RRJ-Express 2 special software (this to the flight data processing).

The difference in the simulation of the RA-89098 airplane flight segments simulation and the type test according to the QTG manual had been that the flight tests as per the QTG are performed in a calm atmosphere to eliminate random processes, associated with the atmospheric turbulence phenomena. As for the tests, arranged by the records of the RA-89098 airplane FDR records, the simulation precision is limited by the accuracy of the wind disturbances record.

To perform tests in the ***automatic mode***[61] the files, submitted by the State Research Institute for Aviation Systems, FSUE, had been uploaded to the simulator. The simulation resulted in the automatic generation of the test reports.

The obtained results are the evidence that the records of the RA-89098 airplane motion dynamics into the flight that ended up with the accident as for the segments in question do not substantially differ from the RRJ-95 aircraft FFS engineering model motion dynamics. The effect of the lightning strike or this by another factors on the FBWCS properties had not been observed.

Fig. 55 presents the outcome of the simulation of the pitch attitudes and AOA change immediately prior the aircraft landing. The plot is given in a relative time, the point of the first touchdown corresponds to the value of 12.5 sec.[62] The plot shows the satisfactory convergence of the recorded parameters and these, obtained at the simulation. The insignificant exceedance of the estimated parameters beyond «the tube» of the QTG acceptable values is explained by the difficulties, mentioned here above, in simulating the ground effect and wind disturbances. At that it is worth noting apart that the material airplane has more damping in pitch channel against the

[61] Thereby the human factor effect (the control by the pilot) had been completely eliminated.

[62] Beyond the indicated timestamp the results of the simulation integrate large errors due to the impossibility to simulate the «impact» against the runway, having been actually accomplished in the flight that ended up with the accident.

FFS. The accomplished changes of the pitch and AOA at the unchanged deflection of the elevator are less at the real aircraft. This finding aligns well with the evaluation by the EASA test pilots (see Section 1.18.19 of the Report).

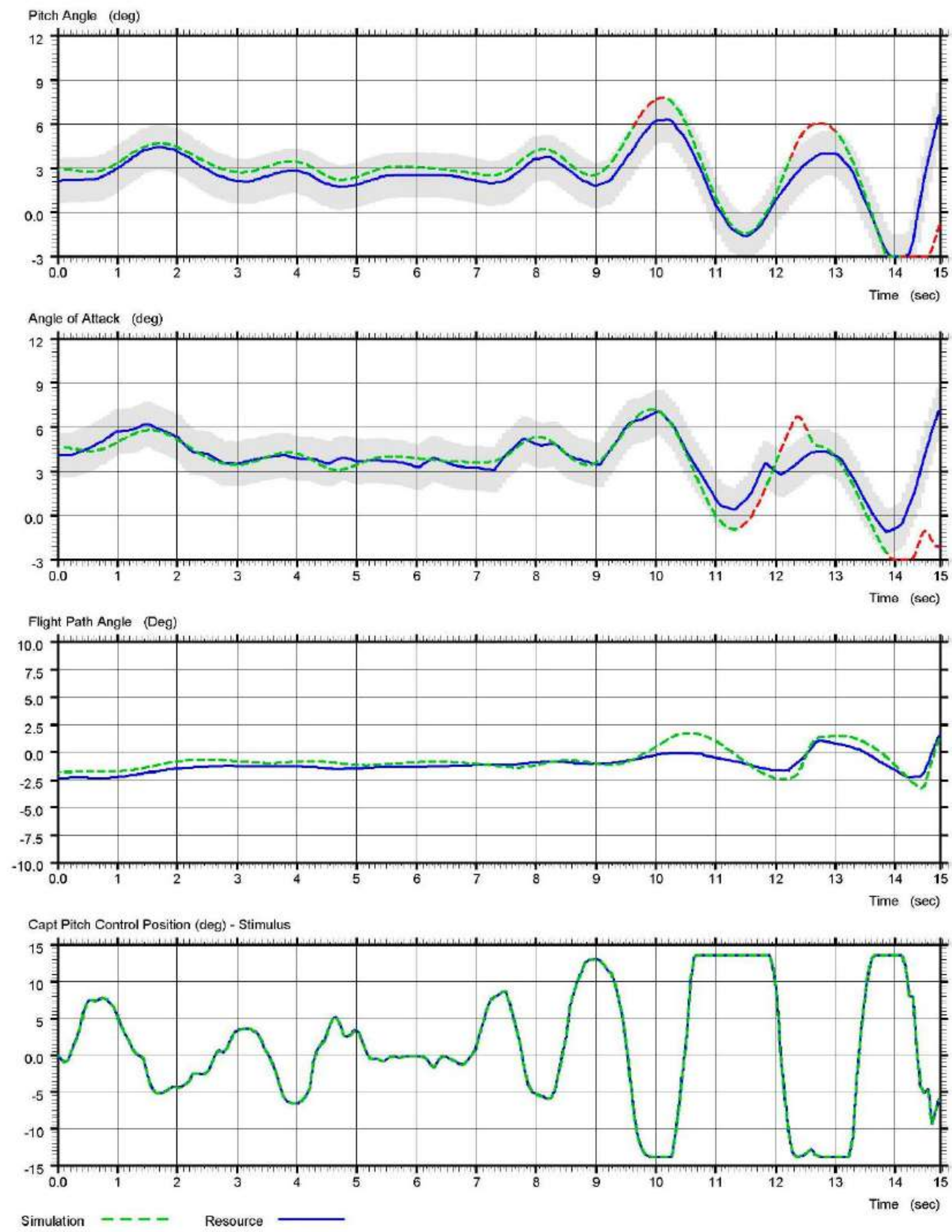


Fig. 55. The simulation outcome (the blue color stands for the recorded parameters, the green one does for the parameters, obtained at the FFS simulation, the red color stands for the region of the exceedance beyond the tube of the QTG (in grey) acceptable limits)

1.16.17. The results of the engineering simulation of the landing gear legs operation

By the request of the investigation team the engineering simulation of the landing gear legs operation was carried out by SAFRAN Landing Systems (SLS), the landing gear designer. The results are presented in the report «MLG aircraft attachment loads analysis for Aeroflot flight SU-1492 on 05 May 2019».

In the course of the analysis the potential for the shock absorbers to bear loads in the conditions of the flight that ended up with the accident had been evaluated. The actual time from the point of the landing gear complete extension to the first touchdown had amounted to about 340 sec. According to the specification, the time, required for the oil and gas to fully settle in their working spaces inside the shock absorbers, amounts to 120 sec. from the point of the landing gear extension. Based on these data the landing gear designer concluded that prior to the first touchdown the landing gear was fully ready to operate.

It had been demonstrated as well that the time intervals of the «airborne» segments between the first and the second and the second and the third touchdowns were enough for the complete extension of the shock absorbers (provided their operation is fully in line with the specification[63]).

The engineering simulation was carried out for the actual values of the landing weight and CG. As per the aircraft recorders data, subject to the actual vertical velocities at the point of touchdowns, as well as the roll and pitch angular rates, the aircraft total energy had been computed.

The vertical velocities values at the runway touchdowns, obtained by differentiating of the radio altimeter readings, amounted to 2.5 m/s, 3.1 m/s and 5.5 m/s respectively. Yet on the aircraft the radio altimeter antennas are installed ahead the MLG legs at the distance of about 7.5 m. That is to say to obtain the respective values of the vertical velocities the obtained values are to be adjusted subject to actual values of the pitch attitude and the pitch angular rate. In view of the stated the estimated values of the vertical velocity at the point of touchdowns had been adjusted. Similarly to compute the vertical velocity values the integration methods of the recorded values of acceleration and the simulation of the aircraft motion had been applied to. The values, obtained with the use of different methods, had the satisfactory convergence. To carry out the further computation the median values had been chosen, amounted to 3.2 m/s, 4.2 m/s and 6.2 m/s to each of three touchdowns respectively.

The ultimate values of the total energy for each of the touchdowns (232 kJ, 583 kJ and 850 kJ respectively) are shown on Fig. 56. The contributions of the total energy constituents for the actual conditions of the landing are marked with the color coding, the red color – out of the angular pitch rate, the green color – out of the roll angular rate, the purple color – out of the potential energy. The Figure shows as well the values (horizontal levels) of the total energy for the occurrences of landing with the maximum allowable landing weight with the vertical velocities of 3.05 m/s (the occurrence of the absorption of the operational energy, consistent with the

[63] The investigation team did not identify any signs of the shock absorbers and aircraft tires non-normal operation.

maximum loads, potential (anticipated) in operation, the «limit loads» in the AR-25 and CS-25 terminology) and 3.74 m/s (the occurrence of the absorption of the maximum energy, consistent with the loads that may be considered as the ultimate ones (or taking into account the safety margin as per item 25.473 (b*), the «ultimate loads» in the AR- 25 and CS-25 terminology)[64], that had been applied to at the certification examination[65].

Note: *The AR-25 item 25.301 «Loads»*

(a) The integrity requirements are determined in terms of limit loads (maximum potential loads in operation) and the ultimate loads (the limit loads, multiplied by the appropriate safety margins).

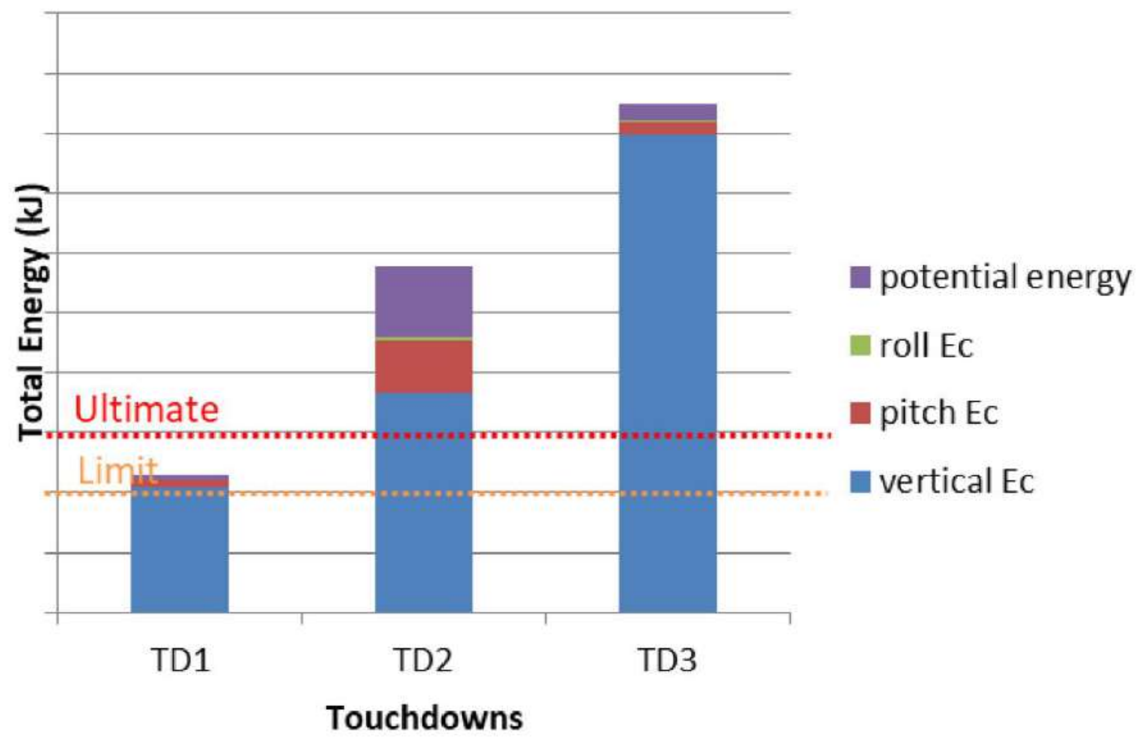


Fig. 56. The total energy contributions by the constituents in the conditions of the flight that ended up with the accident

Based on the total energy calculations the simulation of the landing gear operation at the first touchdown, as the accomplished loads had been less against the ultimate ones, and by the results of the analysis of all the information available there had been no anomalies identified in the landing gear operation at the first touchdown.

The simulation was carried out for the conditions of the aircraft second touchdown.

Fig. 57 and Fig. 58 present the SLS reference axes and the finite element model of the left MLG leg design against the reference axes. On these Figures:

[64] The stated values of the vertical velocities were taken in accordance with the AR-25 item 25.473 (a)(2)(ii) and (a*).

[65] At the computation of the energy to these occurrences the net vertical load out of the landing impact had been meant. The assumption was that there is no aircraft rotation in pitch and roll.

- +X – aft (drag force);
- +Y – to the fuselage (side force);
- +Z – up (vertical force).

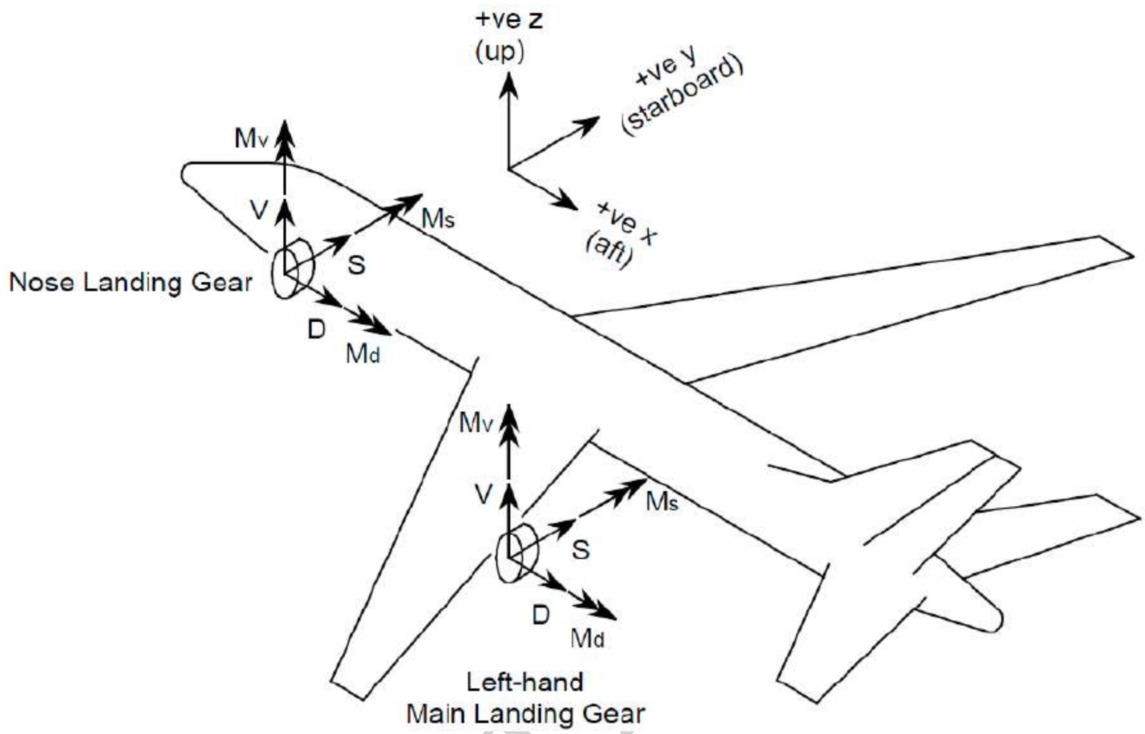


Fig. 57. The SLS reference axes

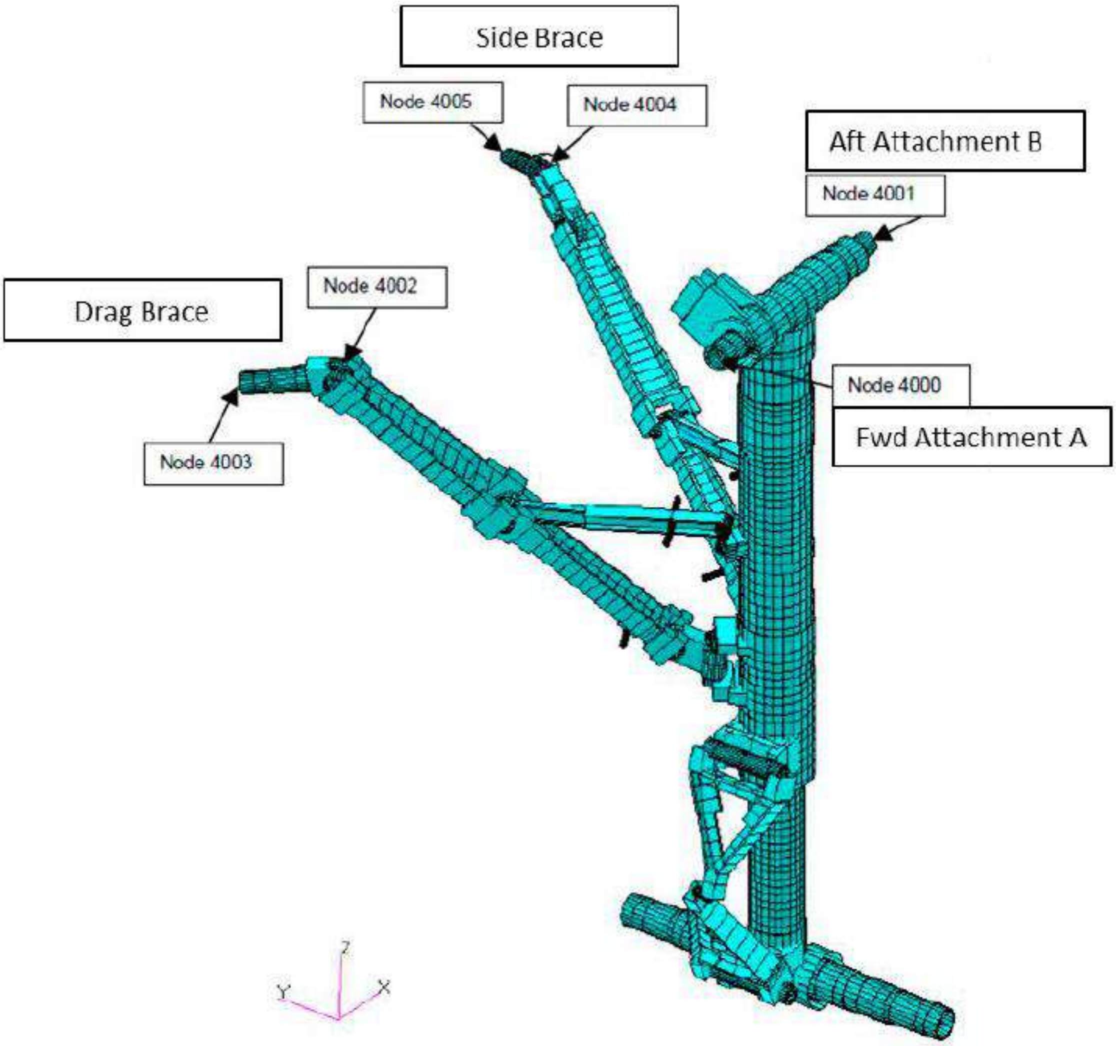


Fig. 58. The left MLG leg finite element model

Proceeding from the value of the absorbed energy at the second touchdown the source data had been obtained for the loading of the MLG leg at the simulation (see the Table here below). The loads are applied at the axle center of the leg.

X (kN), Drag Load	Y (kN), Side Load	Z (kN), Vertical Load	Vertical Axle Travel/VAT (mm),	The tire vertical deformation (mm)
28	0	1111	398	222

The following reaction loads of the landing gear attachment nodes had been obtained as the outcome of the simulation (in the SLS reference frame) (Fig. 59).

Note: *Drag brace and Side brace reaction loads are calculated by a signed resultant from nodes 4002 & 4003 for Drag brace (respectively 4004 & 4005 for Side brace). These reaction loads are oriented along the Drag brace axis (respectively*

Side brace axis) and a positive value means that the part works in traction whereas a negative value means that the part works in compression.

Point	Rx (kN)	Ry (kN)	Rz (kN)	Total (kN)
FWD Attachment A	261	-46	-760	
AFT Attachment B		39	-404	
Side Brace				-380 (compression)
Drag Brace				464 (traction)

Fig. 59. The magnitude of the reaction loads to the MLG leg attachments on the SLS reference axes

The aircraft designer uses different reference axes, where the Y and Z ones are inverted (Fig. 60).

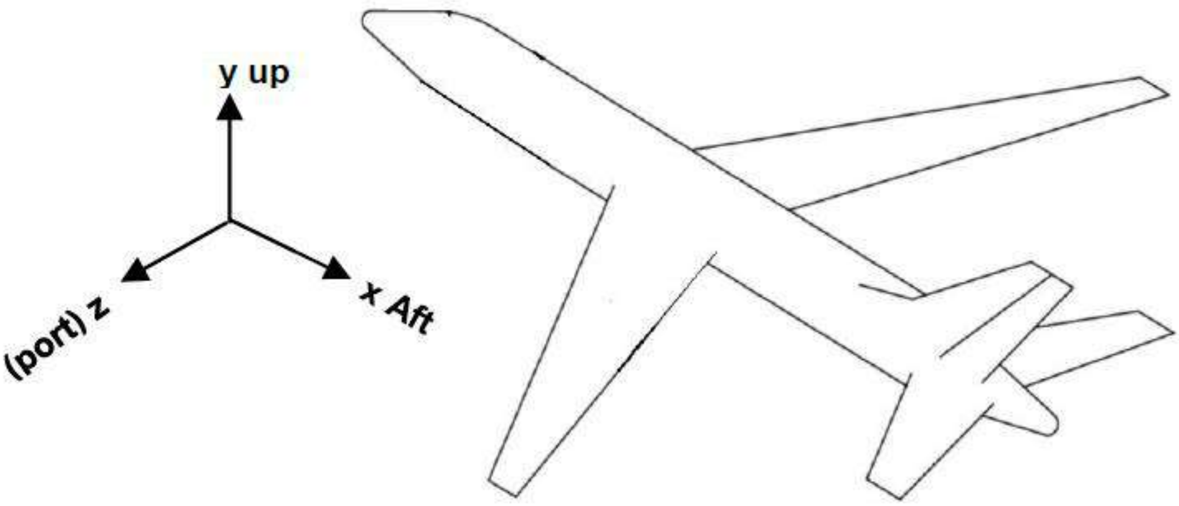


Fig. 60. The reference axes in use by the aircraft designer

Based on the reference system, taken by SCAC, JSC, the results of the simulation (the reaction loads) had been recomputed for the right MLG leg (Fig. 61, the lower Table). For comparison it incorporates as well the magnitudes of the reaction loads at the application of the ultimate loads, having been applied to at the type certification (the upper Table).

Point	Rx (kN)	Ry (kN)	Rz (kN)	Total (kN)
FWD Attachment A	226	-492	-141	
AFT Attachment B		-306	-134	
Side Brace				-679
Drag Brace				748

TABLE 2: CERTIFICATION AIRCRAFT REACTION LOADS ON L/G IN SCAC AIRCRAFT COORDINATE SYSTEM

Point	Rx (kN)	Ry (kN)	Rz (kN)	Total (kN)
FWD Attachment A	261	-760	-46	
AFT Attachment B		-404	39	
Side Brace				-380
Drag Brace				464

TABLE 3: TD2 AIRCRAFT REACTION LOADS ON L/G IN SCAC AIRCRAFT COORDINATE SYSTEM

Fig. 61. The magnitude of the reaction loads at the MLG leg attachment nodes by the SCAC reference axes into the flight that ended up with the accident and at the type certification

Fig. 62 shows the maximum loads, determined in the SCAC, JSC technical design specification for the landing gear design (the ECM RRJ-SU-MD-06-159, MLG Attachment Feasible Loads document). These values had been used by SLS for the landing gear components estimation, including the «weak links» (fuse pins) that had been engineered by SLS.

Point	Rx (kN)	Ry (kN)	Rz (kN)	Total (kN)
FWD Attachment A	190	-525	-199	
AFT Attachment B		-437	-146	
Side Brace				-696
Drag Brace				807

TABLE 6: SCAC ALLOWABLE AIRCRAFT ATTACHMENT LOADS ON THE MLG IN SCAC AIRCRAFT COORDINATE SYSTEM

Fig. 62. The maximum loads on the landing gear attachment elements in the SCAC, JSC reference axes, determined by SCAC, JSC in the technical design specification to design it

The findings as follows derive from the stated data:

- over the Attachment A: the longitudinal and vertical reaction loads (Rx and Ry) had exceeded both these, obtained for the load cases at the certification, and the maximum allowable values, presented by the aircraft designer;
- over Attachment B: the vertical constituent (Ry) exceeded the values, obtained for the load cases at certification, but there had been no exceedance of the maximum allowable ones;

- the actual reaction loads along the drag and side braces did not exceed either the respective values, obtained for the load cases at certification or the maximum allowable ones.

As the reaction loads themselves to the Attachment A and B are not subject to the certification requirements, the accomplished amount of stress to these two nodes and the associated safety margins had been reviewed. The stress analysis was carried out, compliant to the ESR00505-8 RRJ MLG Static Strength Analysis Summary –Part 1 – Issue 3 certification document (pages 70-71). The computation was the evidence that the amount of stress, accomplished into the the flight that ended up with the accident had not exceeded the destructive values for the respective landing gear nodes. The certification ultimate safety margins, calculated by the formula on Fig. 63, amounted to:

- for the Attachment A FWD Trunnion Pin – 79.9 %;
- for the Attachment A FWD Trunnion Pin Flange – 184.2 %;
- for the Attachment B AFT Trunnion Pin – 101.3 %.

$$MS\ (\%) = 100x\left(\frac{Allowable\ Stress}{Effective\ Stress} - 1\right)$$

Fig. 63. The formula for calculating the safety margin

For reference, as far as the indicated attachments are concerned, the report incorporates as well the minimum ultimate safety margins, obtained at the certification activities:

- for the Attachment A FWD Trunnion Pin – 173.9 %;
- for the Attachment A FWD Trunnion Pin Flange – 190.8 %;
- for the Attachment B AFT Trunnion Pin – 145.9 %.

Based on the performed engineering simulation SLS concluded the following:

- the MLG four attachment points – the FWD trunnion pin, the AFT trunnion pin, the drag brace upper cardan pin and the side brace upper cardan pin remained intact;
- the fuse pin to the MLG drag brace remained intact.

Note: *On the results of the examination the landing gear designer (SLS) made the conclusions related to the landing gear structural elements only that had been engineered by it and for which it is responsible. The Attachment A «weak links», the extension/retraction actuating cylinders mounting brackets, as well as the other attachment fittings*[66] *fall under the responsibility of SCAC, JSC.*

[66] For the description of the MLG leg design and attachment see Section 1.18.21 of the Report.

There had been no simulation carried out of the third touchdown, as the second touchdown had resulted in the destruction of the Attachments A «weak links»[67], that is to say the landing gear structure had lost its integrity.

1.16.18. The examination of the fire onset and propagation physics

This section draws on the materials of the Report # И/07-20 of April 23, 2020 by the EMERCOM of Russia Saint Petersburg State Firefighting Service University, FSFEI HE, which, at the request of the investigation team, conducted the examination of the physics of the fire onset and propagation after the landing of the aircraft.

The investigation team raised the issues as follows:

1. What is the sequence (pattern) of the fire propagation through the aircraft fuselage at the aircraft movement on ground and after its stop?

2. The determination of the place, time and direction of initial penetration of the open flame into the aircraft passenger cabin.

3. The determination of the time and disintegration pattern of the cabin windows material at the exposure to the open oriented flame at the area of the fuselage FR24 – 46.

4. What led to a very rapid fire propagation inside the aircraft passenger cabin after the penetration of the open flame (what was burnt so fast, the onset of what processes could have resulted in a rapid propagation of fire inside the passenger cabin)?

Response to issue 1

According to the generally accepted method to determine the sequence of the fire propagation the fire seat should be determined – the point of the fire onset.

For the onset of the fire three material factors should be present, being in interaction:

- the combustible substance;
- the oxidizer;
- the ignition source, capable to induce the reaction between the first two.

In the case under consideration the early stage of the fire had all the signs of the deflagration combustion[68] of the fuel-air mixture: a mixture of combustible gases, vapors or liquid aerosol – fine mist of the combustible liquid - and air.

«The white smoke» that can be seen at the video footage at the aircraft third touchdown, most probably, represented an aerosol cloud, having formed at the initial stage after the loss of structural integrity of the fuel tanks and the release of the jet fuel to atmosphere.

[67] The analysis that supports this finding is outlined in Section 2.3.3 of the Report.
[68] Deflagration is a propagation of flame through a combustible mixture, occurring by diffusion of active sites and heat transfer from the flame front to the unburnt mixture.

The heated surfaces of the running engines of the aircraft could have served the ignition source of the aerosol and the vapor-air fuel mixture. At the inspection of the aircraft, it was determined that the mechanical damage to the fuel tanks was located, inter alia, directly above the engines nozzle. The jet kerosene has a vapor flash point temperature limit of 25 - 65 °C. The temperature of the heated surfaces of the exhaust-mixing nozzle exceeds 150°C. Obviously at the contact with them, with high probability, there could have been the occurrence of the formed fuel-air mixture ignition.

The friction sparks, forming at the impact and friction against the runway or the friction of some single disintegrated aircraft assemblies and parts against each other could have been the second group of the potential ignition sources. The friction sparks are commonly referred to the particles of a substance, formed as a result of impact or friction, heated up to the temperature of the visible glow. These are a relatively common ignition source of the explosive atmospheres, especially when they appear as the consequence of impact, rupture, destruction.

The analysis of the video footage is the evidence that the process, accompanied with the white smoke release abruptly starts and ends in a few seconds. Further on the hydrocarbon fuel combustion process becomes dominant, which is accompanied by the black smoke and flame outburst.

Thus, the external evidence indicates that the early stage of fire was by nature of the formation and the subsequent flash of the gas-vapor-air mixture. The flash occurred towards the rear aircraft section. It was not feasible to determine more to the point the place of the flash due to the destruction and burnout of the aircraft structural elements.

Since the location of the seat of fire is conventionally understood as the place where the combination in time and space of the combustible substance, the oxidizer and the ignition source occurred, as for the subject case, the tail section of the aircraft should be regarded as the seat of fire, as by the location of the above mentioned potential ignition sources – the heated surfaces of the engines and the sparking spots at the friction out of the deformation and destruction of the landing gear parts with the further contact of the aircraft structural elements with the runway.

As it is known the combustion in a fire occurs either in a form of the flame combustion or the heterogeneous one (the smouldering). As for the subject case it had been the occurrence of the flame combustion, the propagation of which had proceeded in a burning fuel vapor phase out of the fire seat.

The video footage shows that after the onset of the steady-state combustion (no later than at 15:30:08) the flame almost immediately envelops the entire rear of the aircraft - from the wing to the empennage. After the aircraft stopped, the fire continued to propagate from the rear of the aircraft to the front.

The fire propagation was proceeded as well from the outside of the aircraft, out of the zone of the intensive burning of the spilling fuel, into the aircraft passenger cabin at its rear part and further along the cabin, from its rear part to the front one.

The fire in the aircraft passenger cabin proceeded in the environment of the limited oxygen content in the air. In such a case the «flashover» could have led to the dramatic increase in the fire area inside the aircraft passenger cabin (see the response to question 4 as well). In the environment of the limited oxygen content in the air the incomplete combustion of the combustible materials occurs with the formation of the smoky aerosol out of the incomplete combustion gaseous products (the carbon monoxide mostly) that are accumulated at the ceiling area. The smoke cloud, accumulated under the ceiling can heat the adjacent fire load (in this instance, the passenger seats, personal belongings, the aircraft cabin interior trim, etc.) by a radiant heat flux to a self-ignition temperature. The rapid propagation of the flame combustion is the result.

The white color of the smoke coming out of the aircraft front left door at the point it was opened after the aircraft stop could have been the consequence of the thermal oxidative breakdown (burning) of the aircraft cabin interior PVC products (the thermal breakdown of the PVC starts with the dehydrochlorination reaction - the elimination of the hydrogen chloride even at the temperatures of 160 - 250°C).

The black color of the smoke along with the erupting tongues of flame at the stage of the developed fire were the evidence predominant combustion of the oil products (in the subject case, this was the TS-1 jet fuel) and the carbon black-charged polymers (the rubber of the aircraft wheels).

Response to issue 2

The inspection was the evidence that the area of the maximum thermal damage of the aircraft cabin is located within the FR40 – 46 (Fig. 42) in the upper fuselage and is manifested in:

– the significant burnout of the aircraft fuselage skin and stiffeners (the frames);

– the complete burnout of the inner skin of the aircraft, the partial charring of the passenger cabin carpeting, the partial burnout and melting of the passenger seats metal frames, the significant burnout of the passenger seats stuffing and upholstery.

The farther from this area the extent of damage is reduced as follows:

– in the aircraft rear passenger cabin (the FR47 – 50) the cabin crew seats foam stuffing and polymer upholstery survived, the passenger cabin interior skin partially survived, the plastic bottles, trays, rags, etc. were preserved in the fire debris, etc.;

– in the area within the FR24 – 40 the passenger seat frames were less burnt out and melted, their upholstery partially survived.

According to the existing method it is generally accepted that the maximum thermal damage is formed as the result of a longer and (or) more intense combustion. More intense combustion may take place due to the accumulation of fire load in the area or the presence of the combustion intensifiers (flammable or combustible liquids).

In this case, the fire load (the passenger seats, interior trim, etc.) is distributed relatively evenly throughout the aircraft cabin; hence, the fire within the FR40–46 proceeded longer than in the other areas of the aircraft cabin.

Thus in view of the above it can be stated that as for the aircraft cabin the onset of fire had been located at the area within the FR40 – 46.

At that as determined by the analysis of the submitted video footage the fire initially started outside of the aircraft and then propagated inside the cabin.

As per the documentation, submitted for the examination, the aircraft cabin windows[69] are manufactured out of the Saint-Gobain Sully Acrylex acrylic glass. The material, used for the cabin windows, is a stretched PMMA that, when exposed to heat, loses its properties.

Note: *According to the details, provided by BEA, the stretching of the material is applied to improve the mechanical properties of PMMA and to meet certification requirements with regards to structural resistance. Nevertheless, when exposed to heat, the material shrinks back. In this way, when heated up to 145ºC, it has to shrink back of at least 37.5%.*

Clearly, at the rear aircraft exposure to the direct and intense fire, which was the occurrence in the case under consideration, the cabin window is to disintegrate faster against the burnout of the aircraft fuselage, which is a metal – non-woven fiberglass material of the 12-25 mm thickness with the PVC panels interior trim sandwich. In the environment when the entire rear aircraft is consumed by the hydrocarbon flame, the outside-in fire development pattern through the melted cabin windows seems the most realistic. This conclusion is also supported by the calculations, shown in the response to issue 3, which were the evidence that the critical heat flux, required to melt the cabin windows, had been significantly exceeded.

As it can be seen at the video footage at the point of the aircraft stop (15:30:38) the fire inside the aircraft cabin is not yet observed, whereas by 15:30:54 the tongues of flame are seen, erupting out of the cabin windows (it had been about 49 sec. from the point of the aircraft third touchdown/the fuel-air mixture ignition).

[69] See Section 1.18.24 of the Report as well.

Thus, it can be concluded that flame combustion inside the aircraft cabin occurred no later than at 15:30:54 (49 seconds from the point of the aircraft third touchdown) after the disintegration (loss of the structural integrity) of the cabin windows.

At that it should be noted that after the aircraft came to a complete stop its entire rear part was consumed by fire, out of which it may be concluded that the fire propagated through the «significant» number of cabin windows at once as from FR40 and along both sides of the aircraft.

Response to issue 3

At the response to this issue two variants of the aircraft windows disintegration have been considered:

– at the exposure to the heat flux out of the burning jet fuel;

– at the exposure to heat flux out of the burning aircraft interior trim.

The heat flux value safe margin as for the material is determined by the comparison of the value of the irradiation intensity under the given fire conditions with the critical irradiation intensity, the excess of which can cause ignition of structures made out of combustible materials.

For the estimation the engineering simulation of the cabin windows warming-up process into two emergency situations (scenarios). It was assumed that the aircraft is stationary.

Scenario # 1:

– at the exposure to the heat flux out of the external source (the burning jet fuel) the warming-up occurs from the outside of the material, out of which the cabin windows are manufactured.

To examine scenario # 1, the process of jet fuel ignition over the volume of the aircraft fuselage was simulated and the values of the critical heat flux, incident on the cabin windows, were computed. The point of the fire onset is the fuel, spilled on the ground (the jet fuel). The height at which the «sensors» for measuring the heat flux, incident on cabin windows, were located was taken to be 1.7 m.

As a result of the computation, the average value of the heat flux, incident on the aircraft cabin windows within FR24-46, was obtained taking into account the absorption of heat by the materials, out of which the fuselage is manufactured. The values of the heat flux exceeding the average values are of a random short-term nature, due to the turbulent flow of the reacting gas mixture, and do not affect the incendiary capability of the heat flux, as for the ignition of the surface by the heat flux, not only its value is important, but also the ignited surface exposure interval. Heat flux values exceeding the critical heat flux values for organic glass are reached in the first 10 seconds of the simulation (fire).

Scenario 2:

– at the aircraft skin exposure to the heat flux out of the external source (burning jet fuel) the ignition of the cabin trim inside the passenger cabin occurs with the warming-up of the material, out of which the cabin windows are manufactured.

At the simulation of scenario # 2 the fire seat was allocated at the tail section of the aircraft, this is required to calculate the heat flux power, incident on the cabin windows out of the aircraft cabin, as if the fire developed from the tail section along the cabin towards the pilot cockpit.

The place of the fire onset was chosen on the basis of the following assumptions. It is known that at the time of the stop, the rear section of the aircraft was consumed by fire. As per the witnesses' evidence the smoke appeared in the tail section of the aircraft cabin and propagated forward along the cabin to the pilot's cockpit.

To compute the heat flux the developed stage of the fire inside the aircraft cabin from the aft wall panel towards the pilot's cockpit was under consideration.

Along with the propagation of the flame front and temperature front, the subsequent fire of the aircraft interior trim panels occurs. The fire load used in the simulation is polyvinyl chloride.

Based on the obtained computed data, the maximum average value of the heat flux density, incident on the inner surface of the aircraft fuselage within 90 seconds from the fire onset did not exceed the critical value of the heat flux for the cabin windows.

By comparing the values of heat fluxes, determined in the progress of the simulation as per two scenarios and affecting the cabin windows from the inside and outside of the aircraft, it can be concluded that the disintegration of the material of the cabin windows at the initial stage of the fire was occurring outside at the exposure to the thermal effect of an open flame, formed out of the combustion of the spilled fuel.

Response to issue # 4

The following first of all contributed to the rapid propagation of fire:

– the depressurization of the aircraft fuel system with the release and burnout of a large amount of hydrocarbon fuel;

– high standard fire load of the aircraft out of the polymer structural materials and cabin interior trim materials, passenger seats, the wire insulation, etc.;

– the aircraft movement into the fire;

– the running engines of the aircraft that additionally fanned the flame and created the effect of «a gas burner».

To assess the impact of the other factors on the fire propagation, including the opening of the left rear door, the computation was made of the distribution of the fire hazards along the aircraft cabin under several scenarios. Given the response to issue 2, the fire seat to simulate the fire hazards was allocated at the area of the FR40 – 46 by the both sides of the aircraft.

Scenario # 1:

– at the exposure to the heat flux out of the external source (the burning jet fuel) there occurs the cabin windows disintegration at the area of the FR40 – 46, and then it is the ignition of the cabin interior trim. Two rear cabin doors are closed, these are only the front doors of the aircraft that are opened.

Scenario # 2:

– at the exposure to the heat flux out of the external source (the burning jet fuel) there occurs the cabin windows disintegration at the area of the FR40 – 46, and then it is the ignition of the cabin interior trim. The left rear cabin door is opened, so are both aircraft front doors.

The fire hazards are as follows:

– the increased ambient temperature;

– the increased concentration of combustion toxic and thermal decomposition products;

– the reduced oxygen concentration;

– the reduced visibility in smoke.

The time, within which each of the fire hazards reaches certain critical values, is subject to computation.

To evaluate the dynamics of the fire hazards at the target points, allocated inside the aircraft cabin, a specialized software was used, developed by the US National Institute of Standards and Technology (NIST) specifically for solving problems in fire safety. The allocation of the «sensors» at the target points inside the aircraft cabin is shown on Fig. 64.

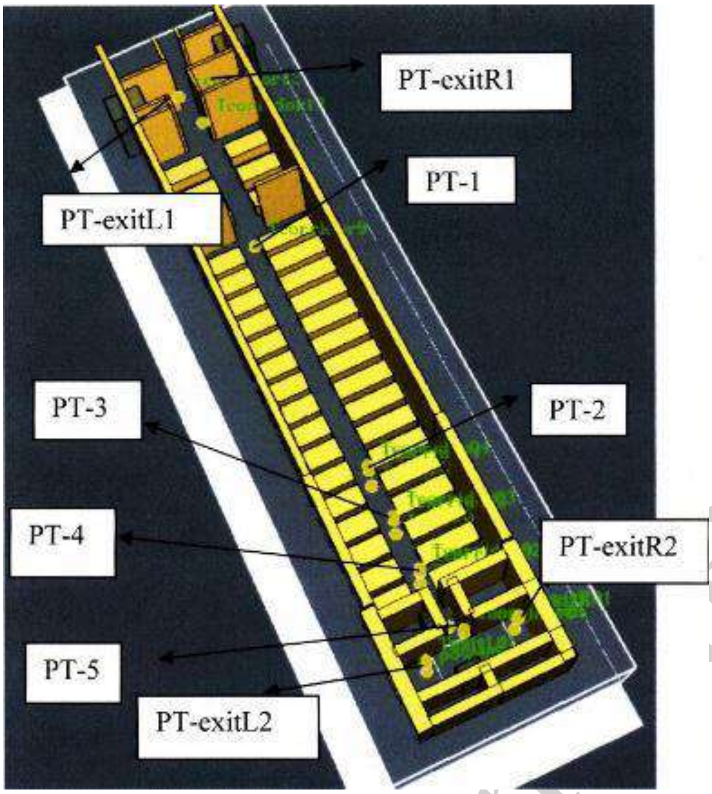


Fig. 64. 3D model of the RRJ-95B aircraft cabin, the target points are marked with yellow dots

The computations were the evidence that the development of fire at the area of the aircraft fuselage FR40 – 46 very quickly results in the temperature increase of more than 600°C at the level of 1.7 off the floor at the region of the PT-2, PT-3 and PT-4 target points both at the opened and the closed left rear door of the aircraft.

Further at these points the estimated temperature reaches the equilibrium value, but the simulation indicates fluctuation (oscillation) of the values around the equilibrium value, whereas at the sufficient amount of oxygen in the room of fire there is a smooth variation of the hazards magnitudes, reaching their critical values along the development of fire. Thus it may be concluded that in the fire in the aircraft cabin there had been the environment of the restricted air supply.

In the environment of the restricted air supply the fire load hot gaseous combustion products are accumulated under the ceiling of the room of fire. The radiant heat flux, oriented downward off this glowing cloud, warms up the fire load, located below, which results in its simultaneous ignition, thereby concurrently increasing the surface of fire. This is called a flashover.

In this way, by the simulation of the fire hazards dynamics inside the aircraft passenger cabin, as well as by the computation of the temperature at the aircraft tail section ceiling area it may be concluded that the rapid increase in temperature resulted in the fast propagation of fire inside the aircraft fuselage and led to the eruption of the fire load and concurrent increase in the fire surface. The position of the left rear door (either opened or closed) could not have significantly affected the fire propagation.

1.16.19. Comparative analysis of the previous approaches and the occurences of the FBWCS reversion to DIRECT MODE

The investigation team carried out the comparative analysis of the final approaches by the PIC to the Sheremetyevo aerodrome RWY 24L at the FBWCS operation in NORMAL MODE performed manually (with the A/P and A/T disengaged), with the flight that ended up with the accident (Fig. 65). The Figure is the evidence that the sidestick pitch inputs into the flight that ended up with the accident, throughout its entire glideslope leg, were much larger in amplitude, oscillatory in nature, which had led to the substantial change in the pitch motion parameters.

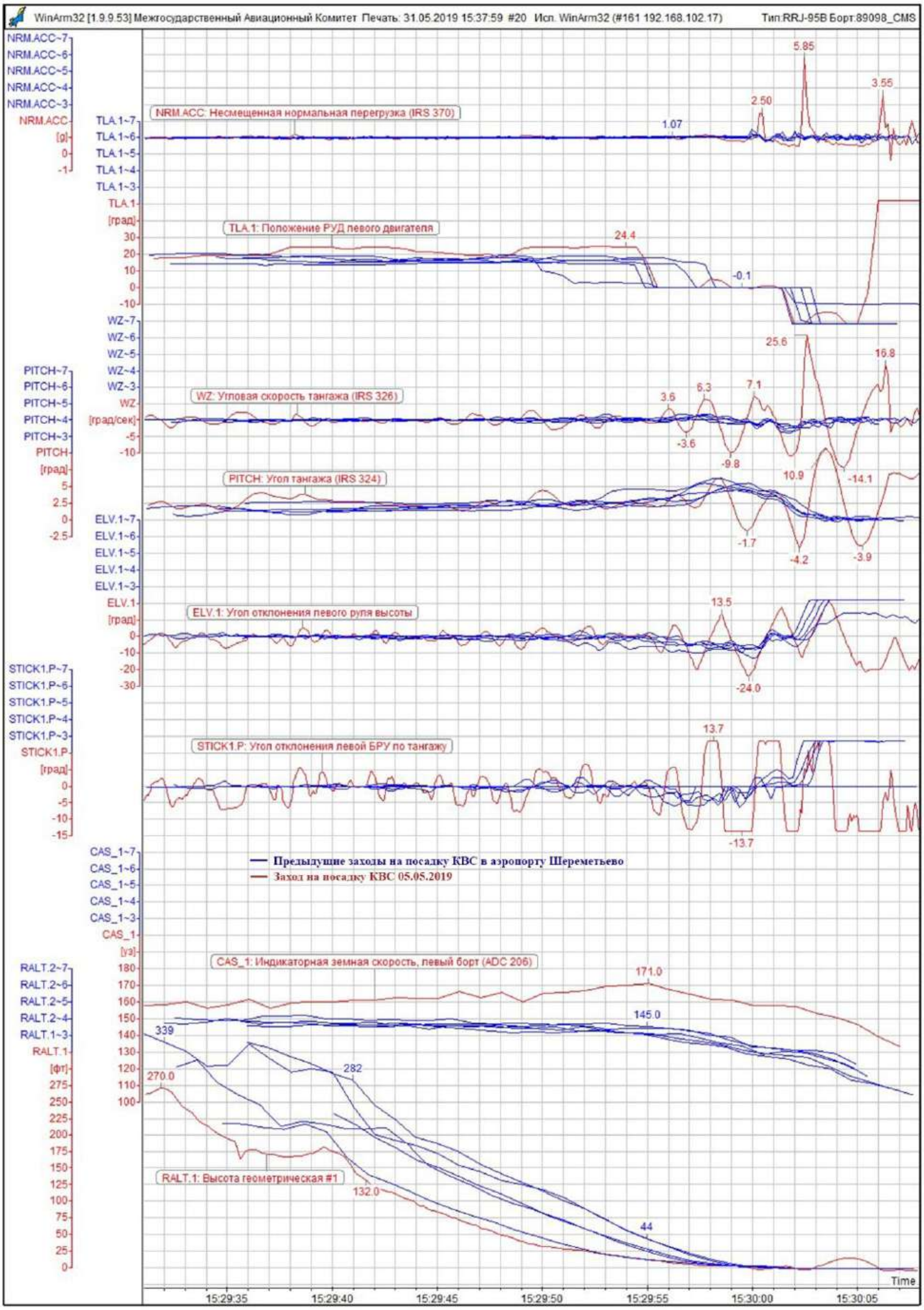


Fig. 65. The comparative analysis of the approaches, performed by the PIC

The similar «sweeping» inputs were also observed at the approaches, performed in DIRECT MODE by another flight crews. The investigation team has reviewed 7 flights, the landing in which had been performed in DIRECT MODE. Six flights out of these were performed by the Aeroflot flight crews and one flight (the RA-89011 airplane), operated by the Yakutiya airline flight crew. Fig. 66 presents the plots of the pitch channel basic parameters change into the glideslope flight vs the flight that ended up with the accident.

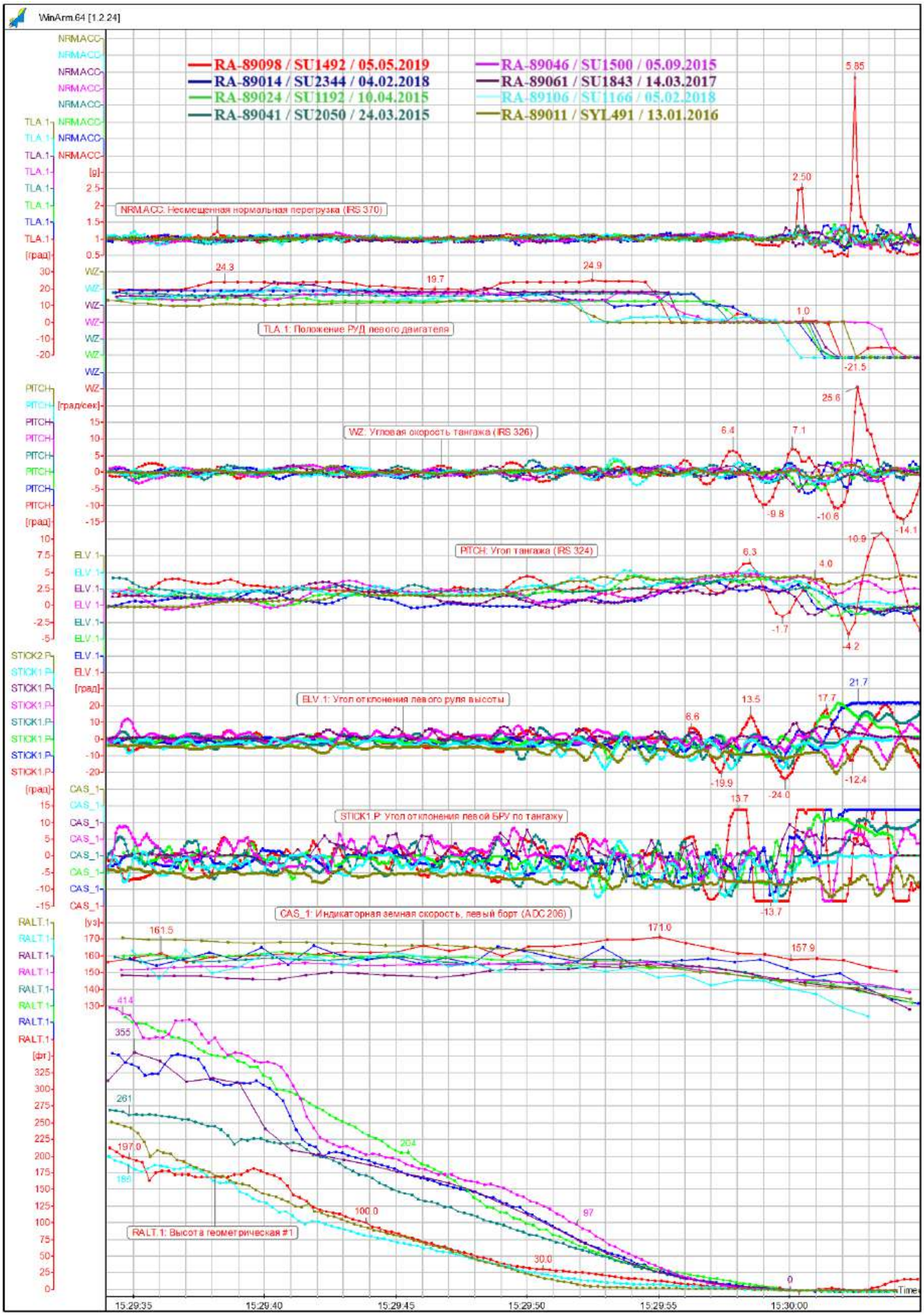


Fig. 66. The comparative analysis of the approaches in DIRECT MODE

The summary table here below, integrating different configurations in the conditions of the trimmed flight,[70] reads the magnitudes of the required sidestick pitch deflection to trim. The values are given as a percentage against the full available travel in the corresponding direction (to nose-down or to nose-up). The minus sign is attributed to the nose-up direction.

Date of the flight, the aircraft tail number	FLAPS ICE	FLAPS 1	FLAPS 2, LG UP	FLAPS 2, LG DOWN	FLAPS 3, LG DOWN	FLAPS FULL, LG DOWN
24.03.2015 RA-89041	-0.7%	-13.9%	-8.4%	-6.1%	-10.5%	-
10.04.2015 RA-89024	2.2%	9.1%	7.3%	21.9%	-10.2%	-
05.09.2015 RA-89046	-3.4%	3.0%	37.7%	36.5%	7.9%	-
13.01.2016 RA-89011	51.1%	22.3%	-	-25.8%	-24.8%	-
14.03.2017 RA-89061	-	-	-	-	-	13.6%
04.02.2018 RA-89014	-	-	-14.6%	-	-10.1%	-
05.02.2018 RA-89106	-	-16.4%	-8.8%	0.9%	-17.2%	-
05.05.2019 RA-89098	-7.3%	-14.6%	-	0.7%	-15.3%	-

Fig. 67 presents the plots of the parameters change at the approach and landing of the RA-89041 aircraft. The following features are observed:

- the amplitude alternating sidestick inputs of a high frequency at flare[71] and right before it (the singled-out region on the Figure);
- the RWY threshold flyover at the altitude of 25 ft.
- the sidestick forward inputs of 4.1° after the threshold flyover, of 2.5° at the flare;
- at the point of landing the pitch is equal to 2.7° to nose-up, the sidestick is in almost full back position;
- the loss of the MLG WOW signal and another insignificant bounce off the RWY;
- the TL were retarded to REV detent at the bounce off the RWY;
- first the TR were deployed, the speedbrakes were manually deployed afterwards.
- into the landing roll the forward sidestick input up to the full travel.

[70] No numerical values into several cells of the table (the «-» symbol is put) imply that either it had not been the case of the relevant configuration accomplishment at the FBWCS in DIRECT MODE or there is no trimmed leg of the flight in this configuration.

[71] According to FCOM (Section 1.09.11 page 6), into the stabilized approach the top of flare is at 30-20 ft AGL roughly. Since throughout the flights, subject to consideration in the Report, the stabilization criteria had not been met to some extent, so at this Section the flare refers to the flight leg, beginning either from the indicated altitude, or when the pitch attitude to establish the landing attitude starts to increase, or with the TL repositioning to the IDLE detent (whichever occurred earlier), and ending with the runway touchdown.

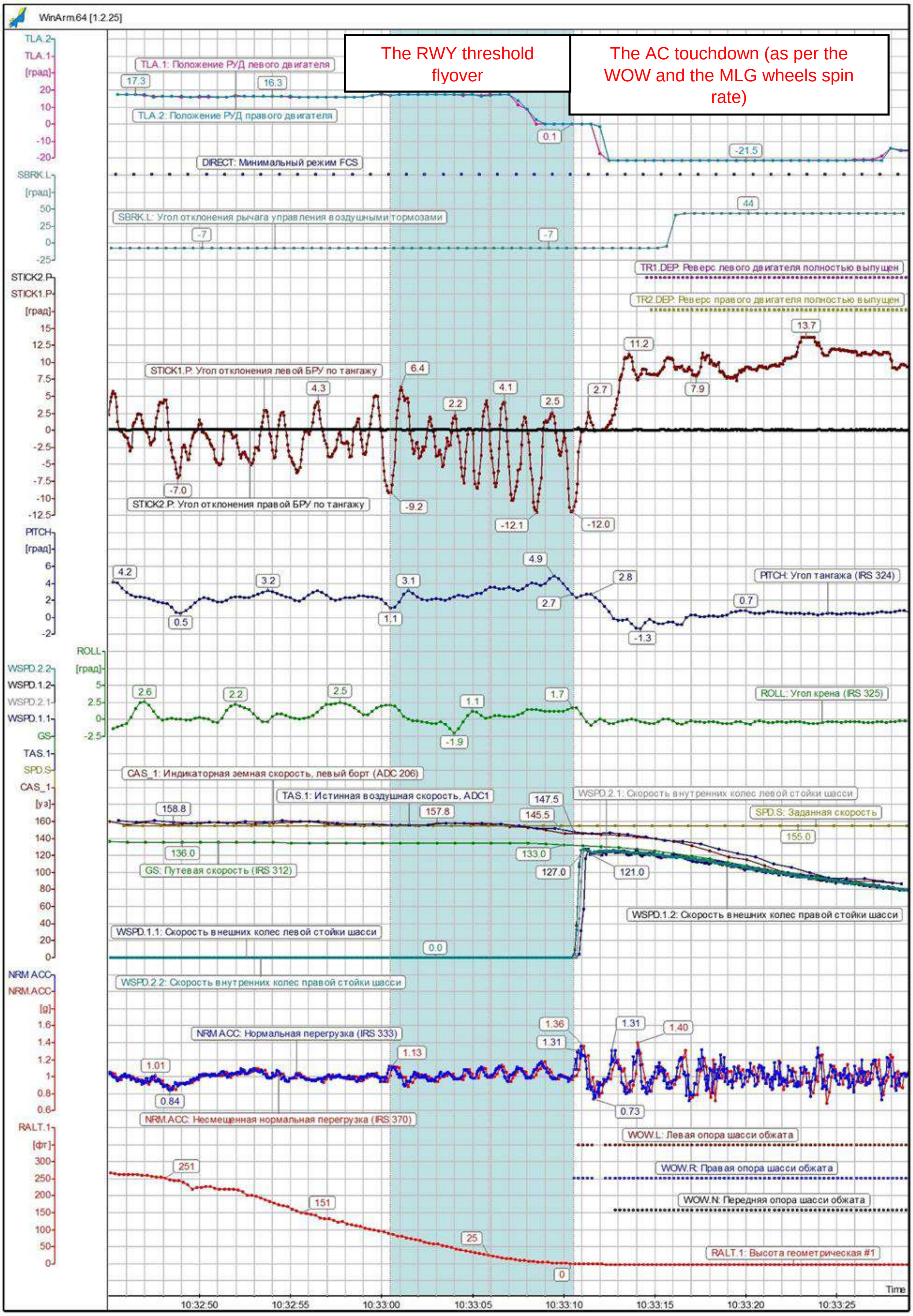


Fig. 67. The approach and landing in DIRECT MODE of the RA-89041 airplane on 24.03.2015

Fig. 68 presents the plots of the parameters change at the approach and landing of the RA-89024 aircraft. The following features are observed:

- the amplitude alternating sidestick inputs of a high frequency at the flare and immediately before it (on the Figure the region is highlighted with the grey color);
- the RWY threshold flyover at the altitude of 34 ft.;
- the forward sidestick inputs after the RWY threshold flyover up to 3.2°, after the TL setting to the IDLE detent – up to 4.4°;
- the long-time landing roll with no «steady» WOW to the NLG (on the Figure the region is highlighted with the red color);
- first the TR were actuated, the speedbrakes were manually deployed afterwards.

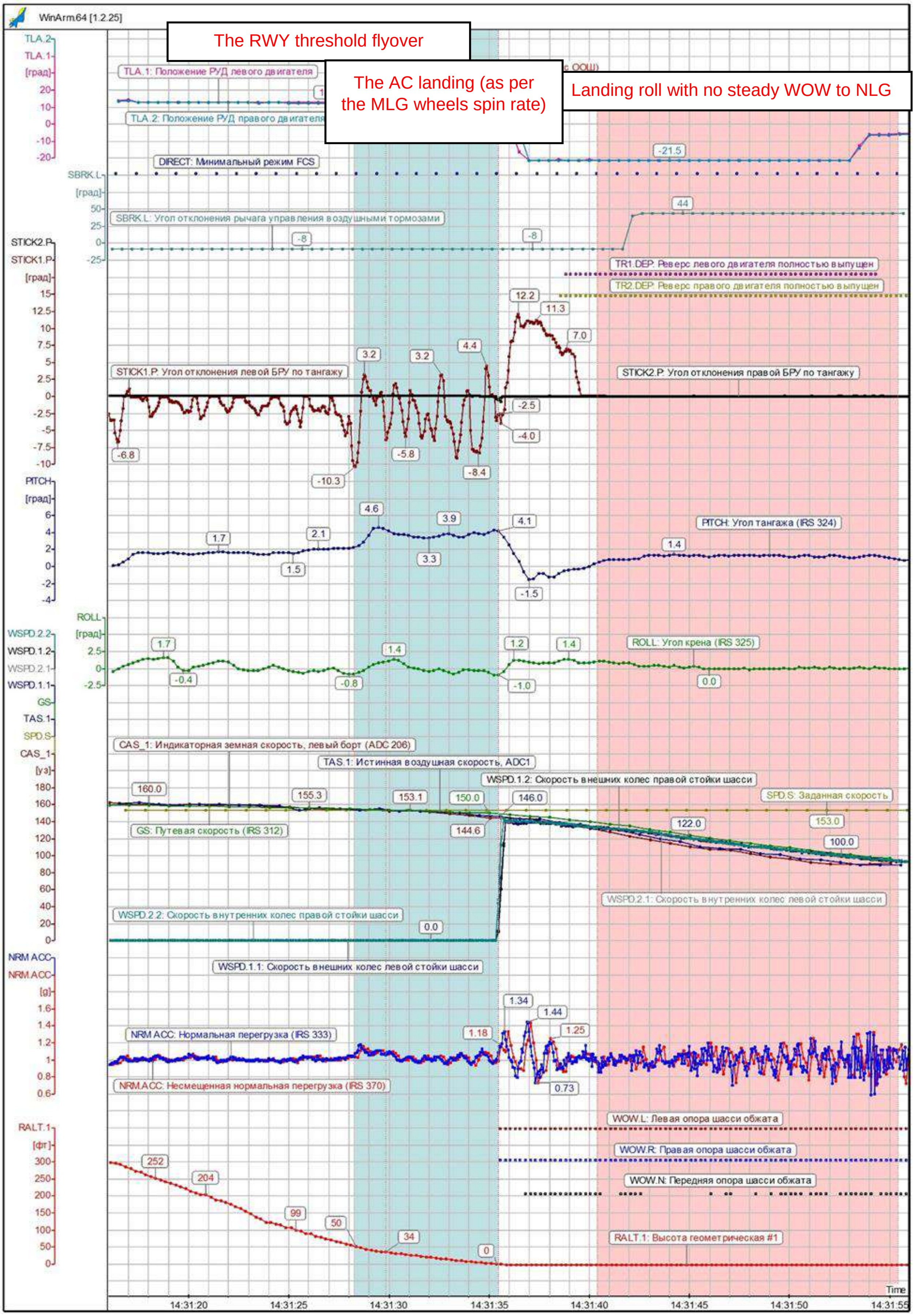


Fig. 68. The approach and landing in DIRECT MODE of the RA-89024 aircraft on 10.04.2015

Fig. 69 presents the plots of the parameters change at the approach[72] and landing of the RA-89046 aircraft. The following features are observed:

- the amplitude alternating sidestick inputs of a high frequency at the flare and immediately before it with the «dual input»;
- the forward sidestick input of 2.6° at flare;
- there had been two aircraft bounces off the RWY (it is highlighted on the Figure);
- into the bounces the sidestick amplitude alternating inputs (half travel forward and up to the full aft inputs);
- the high-rate sidestick inputs at the point of the touchdowns;
- first (at the third touchdown) there had been a manual deployment of the speedbrakes, the TR were actuated afterwards;
- the «prolonged» lowering of the NLG
- the forward sidestick input at the landing roll

[72] The parameters of the second approach are stated, at the first approach the go-around was initiated from the altitude of 270 ft (~ 80 m). This flight is subject to the detailed analysis through this Section here below.

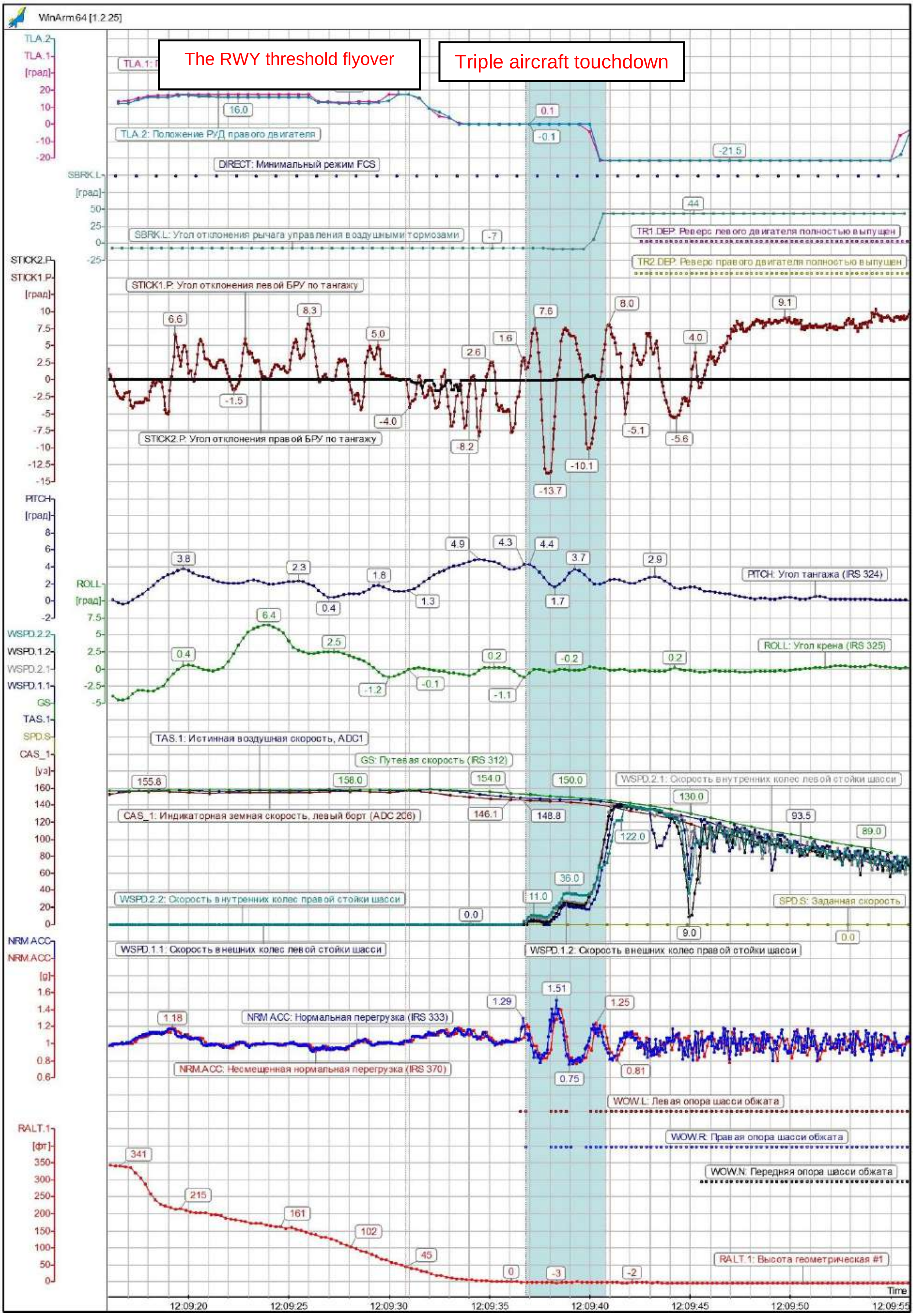


Fig. 69. The approach and landing in DIRECT MODE of the RA-89046 aircraft on 05.09.2015

Fig. 70 presents the plots[73] of the parameters change at the approach and landing of the RA-89061 aircraft. The following features are observed:

- the FBWCS reversion to DIRECT MODE occurred in the landing configuration into the glideslope leg of the flight at the altitude less than 500 ft., when the aircraft had been fully trimmed in the automatic flight;
- the amplitude alternating sidestick inputs of a high frequency at the flare and immediately before it;
- the forward sidestick inputs after RWY threshold flyover up to 4.7°, at the flare – up to 3.7°;
- at the point of landing the pitch was equal to ~ 2° to nose-up;
- first the TR were actuated, the speedbrakes were manually deployed afterwards.

[73] As for this flight, there had been no DAR record available to the investigation team. A number of the parameters (a LG wheel spin rate, for example) had not been available for the analysis either.

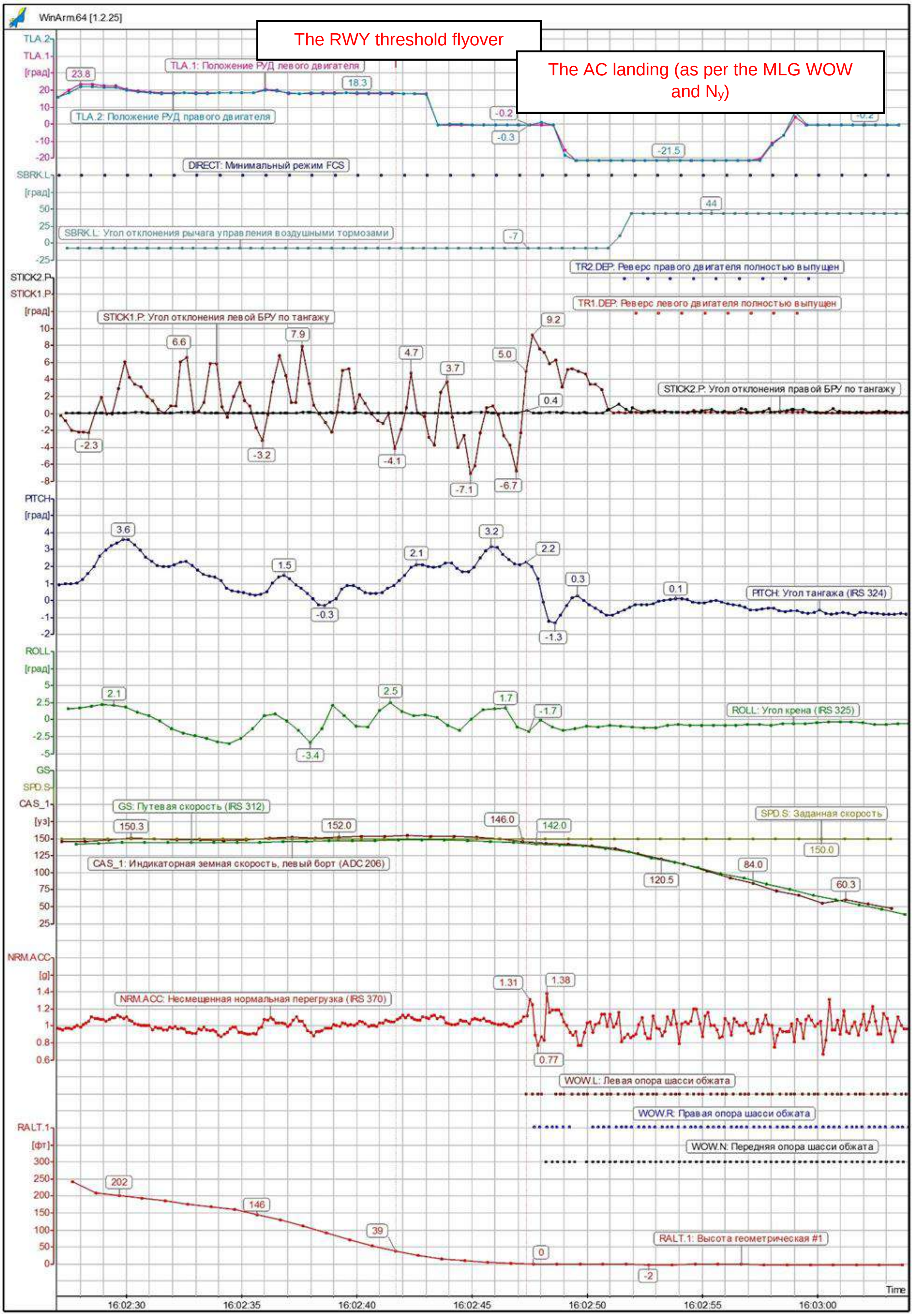


Fig. 70. The approach and landing in DIRECT MODE of the RA-89061 aircraft on 14.03.2017

Fig. 71 presents the plots of the parameters change at the approach and landing of the RA-89014 aircraft. The following features are observed:

- the forward sidestick inputs of more than 2.4° at flare;
- at the point of landing the pitch value is equal to ~ 3° to nose up, the right roll of ~ 3°;
- initially the landing roll with the right roll of up to 3.5° (it is highlighted on the plot) with the stop of the left MLG WOW discrete signal record;
- first the TR were actuated, the speedbrakes were manually deployed afterwards;
- full forward sidestick input at the landing roll.

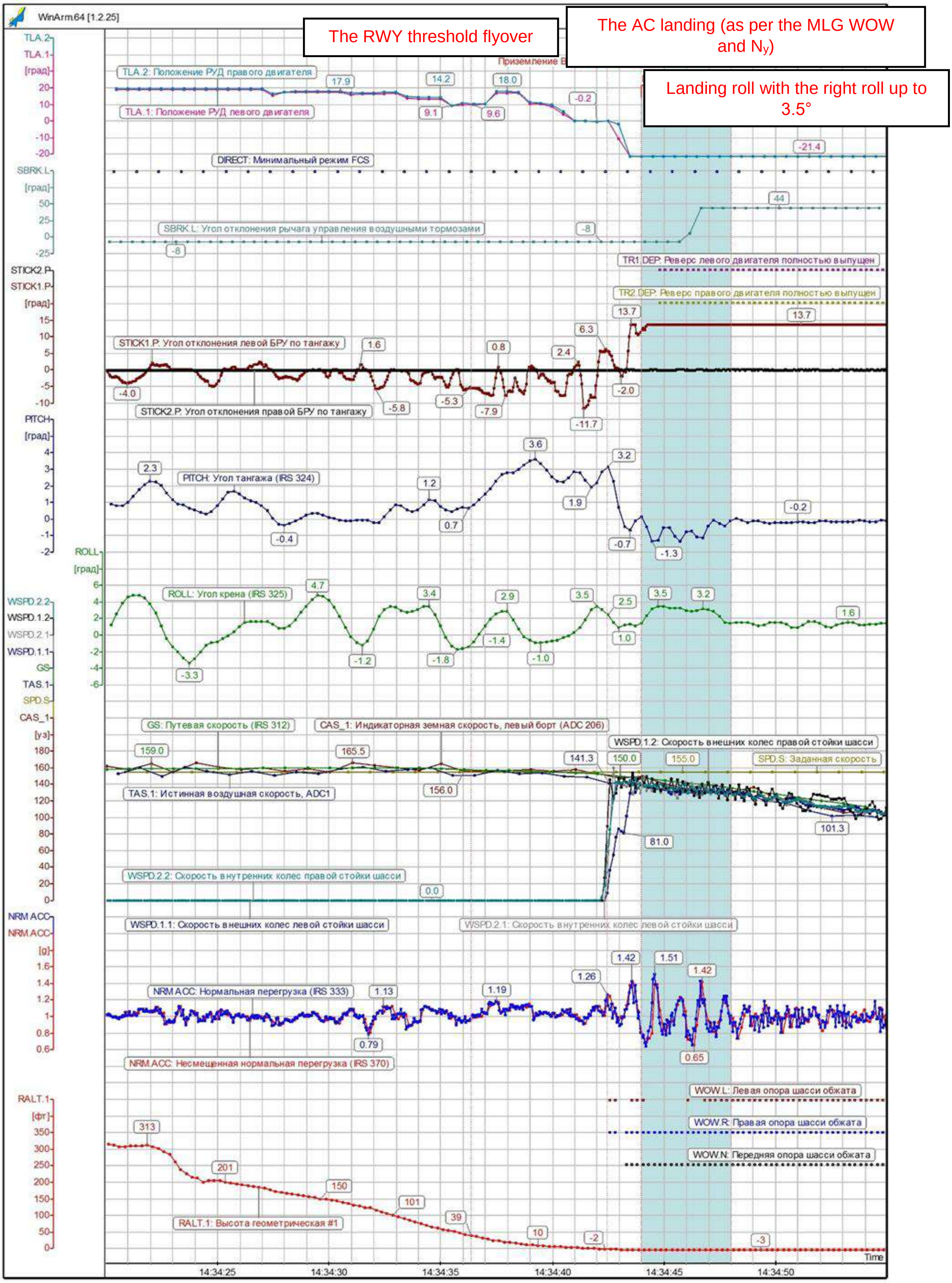


Fig. 71. The approach and landing in DIRECT MODE of the RA-89014 aircraft on 04.02.2018

Fig. 72 presents the plots of the parameters change at the approach and landing of the RA-89106 aircraft. The following features are observed:

- the RWY threshold flyover at the altitude of 26 ft.;
- the prolonged flare (it is highlighted on the plot);
- the amplitude alternating sidestick inputs of a high frequency at flare up to the nearly full back inputs and the forward input up to 4.6°;
- another bounce off the RWY, the first touchdown at the distance of 770 m off the RWY entry threshold, the second one at the distance of 865 m;
- first the TR were actuated, the speedbrakes were manually deployed afterwards.

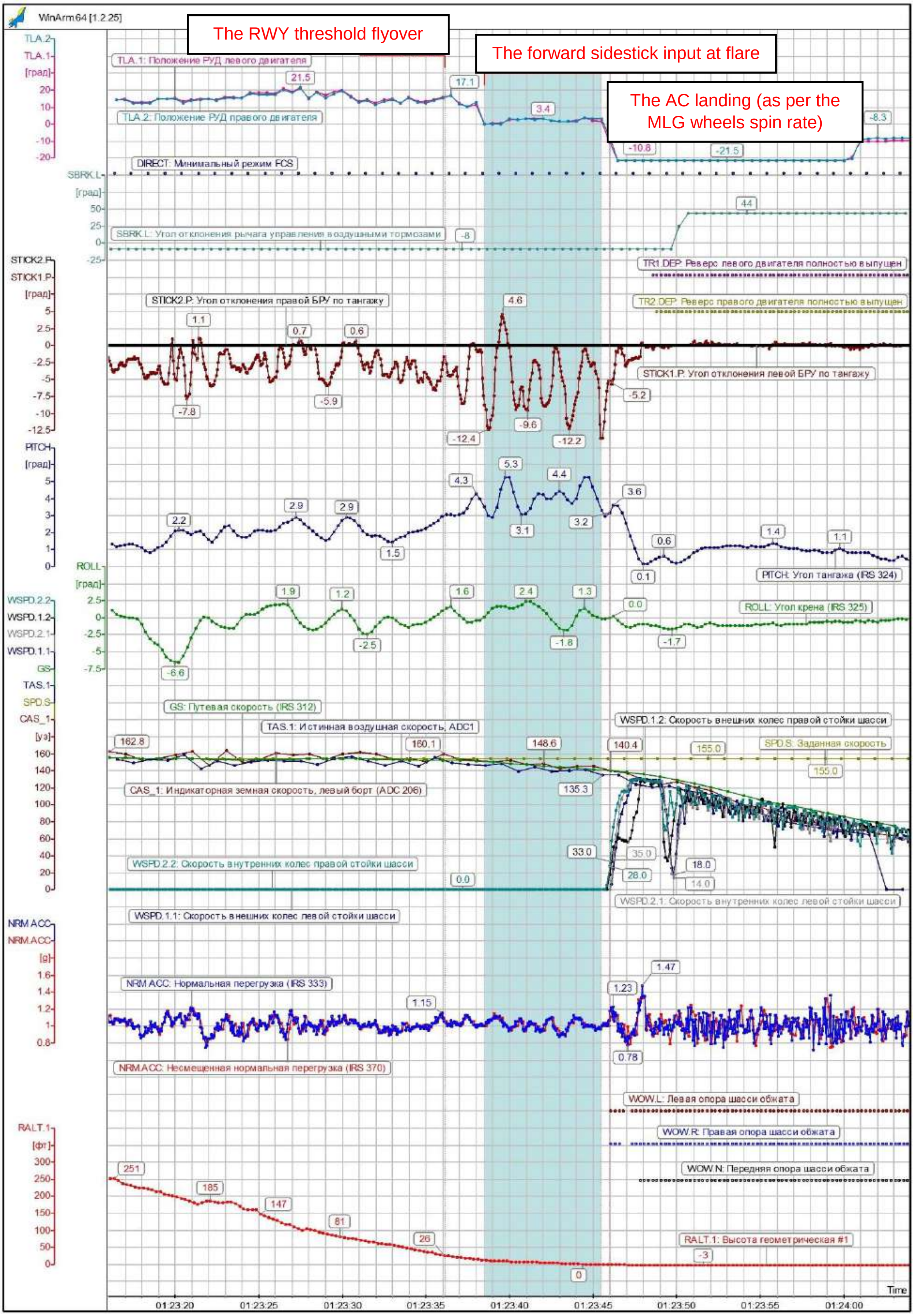


Fig. 72. The approach and landing in DIRECT MODE of the RA-89106 aircraft on 05.02.2018

Fig. 73 presents the plots of the parameters change at the approach and landing of the RA-89011 aircraft. The following features are observed:

- the RWY threshold flyover at the altitude of 33 ft.;
- the prolonged flare;
- DUAL INPUT on the final leg, including the flare, one of the sidesticks had been repositioned forward up to 1.9°;
- two aircraft bounces off the RWY (highlighted on the Figure), the first touchdown at the distance of 865 m off the RWY threshold, the third one – at the distance of 1150 m. Into the bounces off the RWY the high-rate sidestick inputs were observed, at that the second sidestick had been repositioning forward (dual input);
- at the third touchdown the TR and the manual speedbrakes deployment occurred nearly simultaneously.

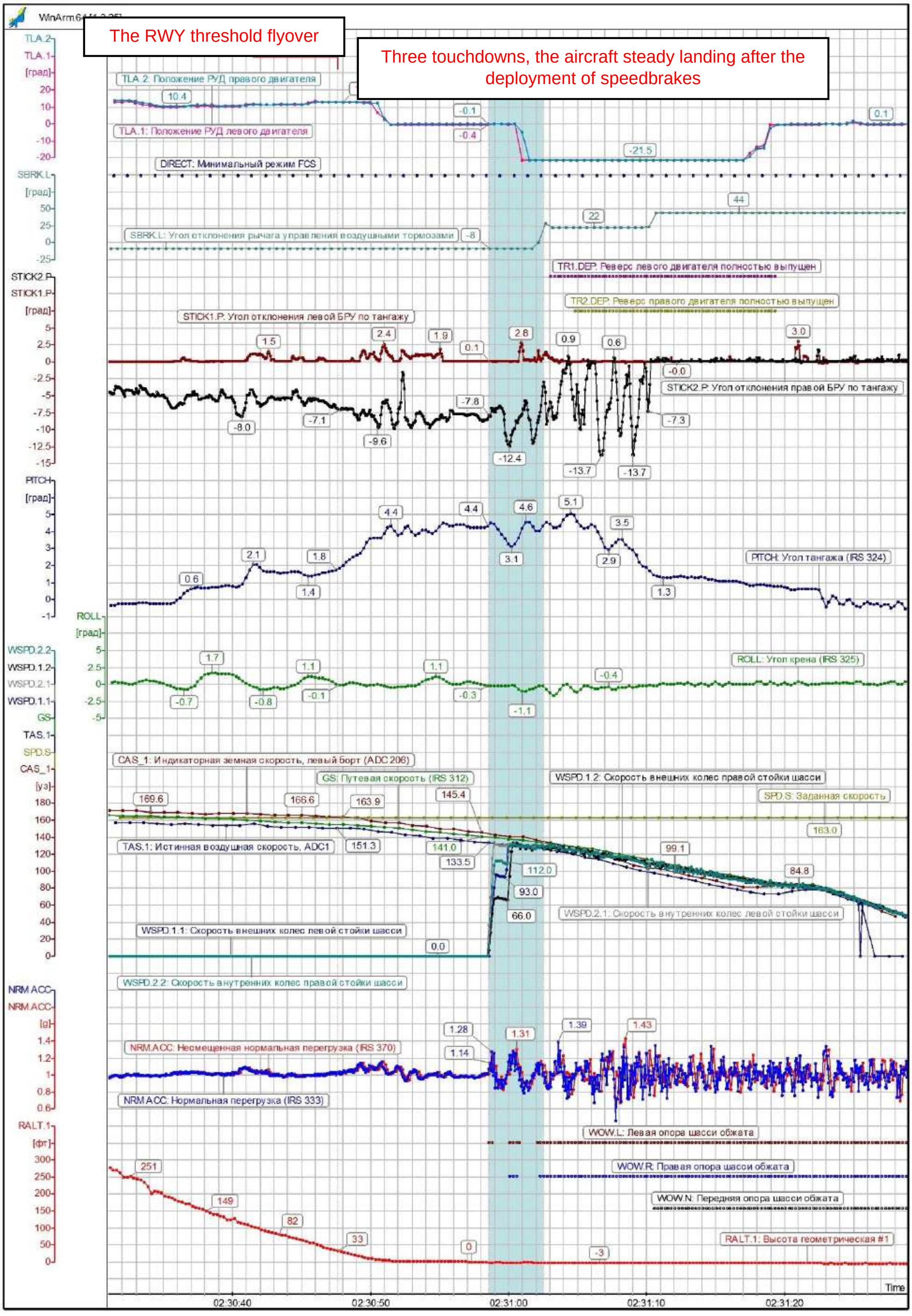


Fig. 73. The approach and landing in DIRECT MODE of the RA-89011 aircraft on 13.01.2016

The analysis outcome suggests:

- in all the cases into the glideslope flight the aircraft were significantly unbalanced (out-of-trim) in pitch, which had required the sidestick input to trim of between 8 and 17% of full travel. In two cases the required trim input had been to nose-down, in four cases it had been to nose-up;
- the correlation is observed: the more is the magnitude of the aircraft out-of-trim condition, the more sidestick control inputs are amplitude/«sweeping» at the glideslope[74];
- in 4 flights out of 7 the RWY threshold had been flown over at the true altitude much less than 50 ft.
- in 6 flights out of 7 the flight crews experienced apparent difficulties in proceeding flare, landing and initial landing roll. Into the only flight where this had not been pronounced, the reversion to DIRECT MODE had occurred at the glideslope flight at the altitude of 500 feet. At the point of reversion the aircraft was flown automatically and trimmed;
- through all the flights the forward sidestick inputs in pitch beyond neutral are recorded after the initiation of flare;
- in 5 flights out of 7 the sidestick inputs in pitch had been of a distinct oscillatory nature. In two flights at flare there had been the aft sidestick inputs up to the full travel with the elevator actuators reaching limit values of the deflection rate, in two other flights the dual input had been recorded;
- in the flights of 05.09.2015 and 13.01.2016 two consecutive bounces off the RWY were observed. The landing roll was initiated only after the third touchdown. In both cases at the third touchdown the flight crew deployed speedbrakes manually;
- in 5 flights out of 7 after touchdown the flight crew applied TR first and the speedbrakes afterwards.

The table here below presents the summary of findings regarding the flight crew actions based on the results of the investigation of the previous events in question of the FBWCS reversion to DIRECT MODE.

[74] Additionally the test pilots to the aircraft designer, having wide experience of the flight training, expressed the opinion that the amplitude/«sweeping» nature of the inputs involves the inadequate skills of raw data approach.

The date of the flight, aircraft tail number	The results of the investigation in terms of the flight crew's actions assessment
24.03.2015 RA-89041	The investigation had been conducted by the FATA Central Interregional Territorial Department investigation team. The representatives of the aircraft designer and operator had been appointed to the investigation team. The Report on the results of the investigation had been approved on 13.04.2016. As for the flight crew actions it had been concluded: *«The actions by the aircraft flight crew after the onset of the occurrence had been appropriate and complied with the RRJ-95B FCOM and the operator OM (parts A and B)* ».
04.10.2015 RA-89024	No information on the conduct of the occurrence investigation is available.
05.09.2015 RA-89046	No information on the conduct of the occurrence investigation is available.
13.01.2016 RA-89011	The investigation had been conducted by the FATA Sakha (Yakutia) Interregional Territorial Department investigation team. The Report on the results of the investigation had been approved on 22.01.2016. The representatives of the aircraft operator had been appointed to the investigation team. As for the flight crew actions it had been concluded: *«Based on the review of the flight crewmembers' explanatory notes and the Report on the results of the FDR data decoding the actions by the crew had been in line with the RRJ-95B QRH, FCOM»*.
14.03.2017 RA-89061	The investigation had been conducted by the FATA Central Interregional Territorial Department investigation team. The representatives of the aircraft designer and operator had been appointed to the investigation team. The Report on the results of the investigation had been approved on 05.12.2017. As for the flight crew actions it had been concluded: *«Based on the analysis of the data, recorded by the RRJ-95B 89061 aircraft FDR at the performance of the SU-1843 flight, it had been determined that the flight crew allowed violating the flight operation rules:* *– at the transition altitude the STD pressure (the left side) had not been set from 14:59:05 till 14:59:56;*

	– at the transition altitude the STD pressure (the right side) had not been set from 14:29:06 till 14:59:56; *The mentioned violations are not causally related to the in-flight onset of the emergency».*
04.02.2018 RA-89014	The investigation had been conducted by the FATA Central Interregional Territorial Department investigation team. The representatives of the aircraft designer and operator had been appointed to the investigation team. The Report on the results of the investigation had been approved on 02.03.2018. No conclusion had been stated on the flight crew actions, no shortcoming had been noted as for the operation in DIRECT MODE.
05.02.2018 RA-89106	The investigation had been conducted by the FATA Central Interregional Territorial Department investigation team. The representatives of the aircraft designer and operator had been appointed to the investigation team. The Report on the results of the investigation had been approved on 02.03.2018. No conclusion had been stated on the flight crew actions, no shortcoming had been noted as for the operation in DIRECT MODE.

In view of the apparent difficulties in performing flights in DIRECT MODE that had been observed at different flight crews the fact that they had not been subject to analysis, and, as a consequence, any respective Safety Recommendations had not been issued, indicates the insufficient quality and depth of the investigation. As per the information available two occurrences had not been investigated at all.

The following are more detailed data on the occurrence to the RA-89046 aircraft. The FDM forms to this flight, submitted to the investigation team, are the evidence that most deviations, indicated here below, had been detected in the automatic mode. Nevertheless the investigation team had not been communicated on any investigation of the occurrence (either by FATA or the airline itself).

The FCS reversion to DIRECT MODE occurred at 11:13:25 in the progress of the cruise flight on FL340 and at the IAS of about 265 kt, the TLA was 25.3°, N1 - 85 % (Fig. 74). The aircraft had been flown in the automatic mode. The first control inputs by the crew after the reversion to DIRECT MODE, accompanied by the AP disconnect, had been recorded not earlier than in about 17 sec. Since then the aircraft pitch smoothly changed from 2.7° to nose-up to 1.3° to nose-down. Eventually the aircraft «ran away» by about 500 ft. down from the cruise FL. This evidence shows the flight crew’s insufficient situational awareness and the inadequate monitoring of the flight parameters and the AP operation.

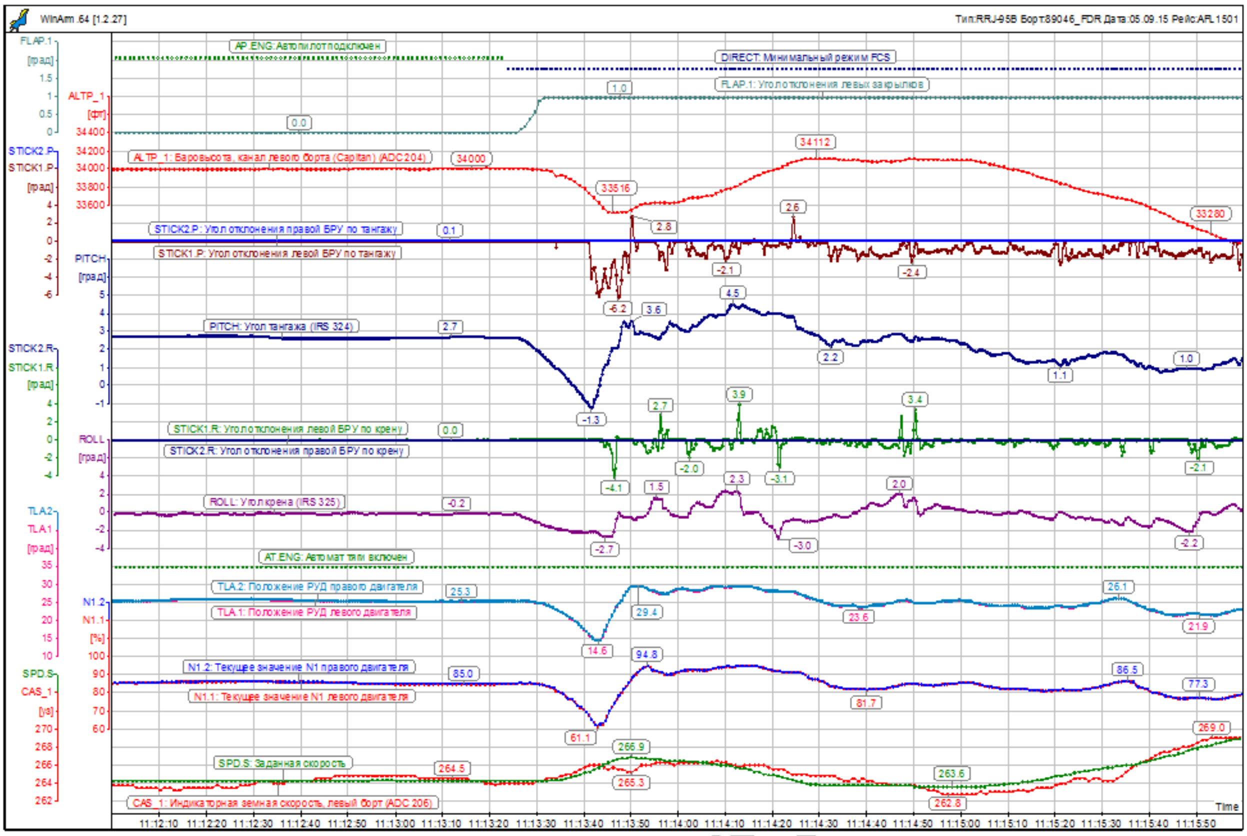


Fig. 74. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the FBWCS reversion to DIRECT MODE

Fig. 75 presents the flight data of the flight on FL280. Apparently the piloting was focused on the maintenance of the target altitude. The flight was proceeded at the IAS of about 280 kt that was maintained by the A/T. That is to say, after 10 minutes approximately from the FBWCS reversion to DIRECT MODE the crew, in non-compliance to the FCOM, did not disengage the A/T. The A/T was disengaged at no earlier than 11:41:25.

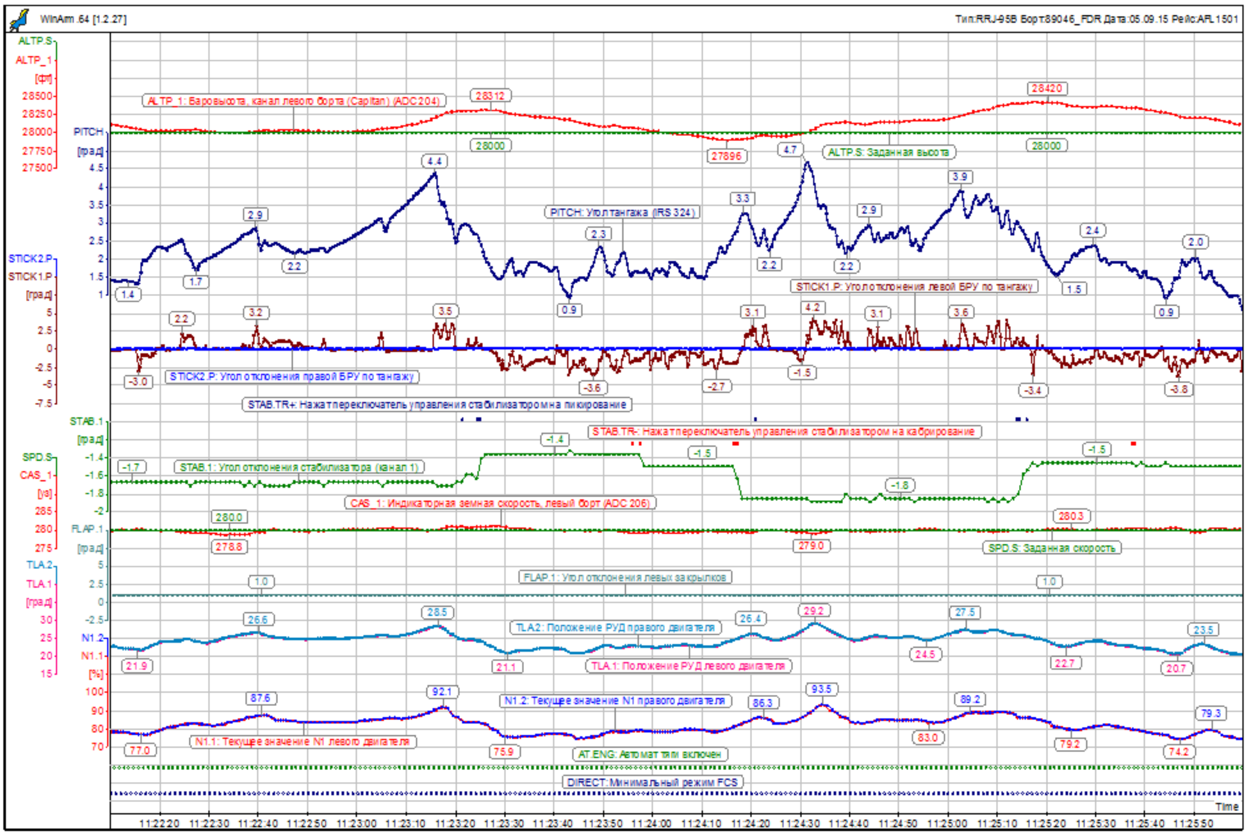


Fig. 75. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the flight on FL280

At the beginning of the interval under consideration the stabilizer is deflected to 1.7° to nose-up. The plot is the evidence that this setting is clearly excessive against the current flight parameters. At the sidestick release to neutral the aircraft was starting to pitch up intensely. Further on the pilot undertook several stabilizer resettings to both nose-up and nose-down and, finally, set it to the 1.8° position, which, naturally, did not improve the situation – at the sidestick return to neutral the aircraft continued to pitch up, the departure off the target altitude amounted to more than 400 ft. It was just the subsequent stabilizer setting to the 1.5° to nose-up that slightly rectified the situation.

A similar pattern with the aircraft pitching up at the release of the sidestick to neutral was repeated when trying to maintain the FL80 (Fig. 76). At this stage the pilot never attempted to trim the aircraft.

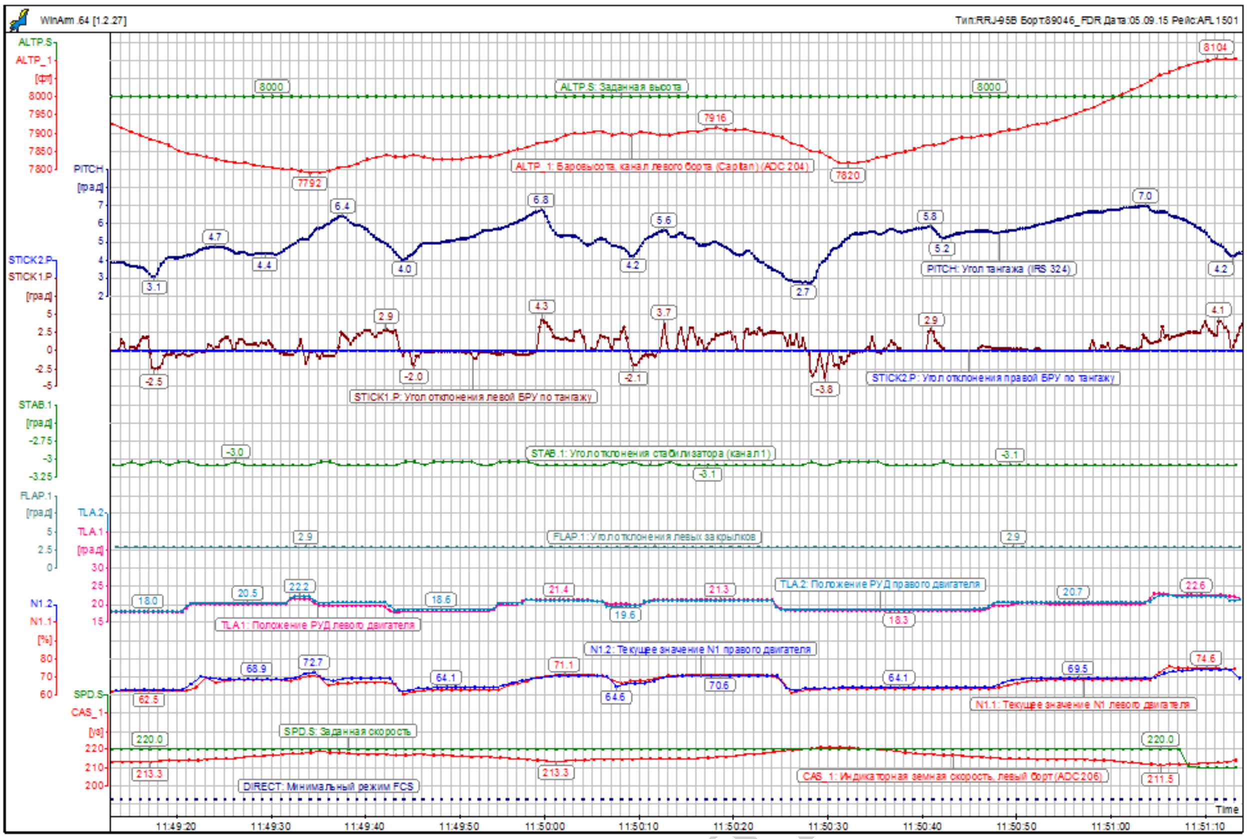


Fig. 76. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the flight on FL80

Fig. 77 and Fig. 78 present the flight data in the pitch and lateral channels respectively at the first approach.

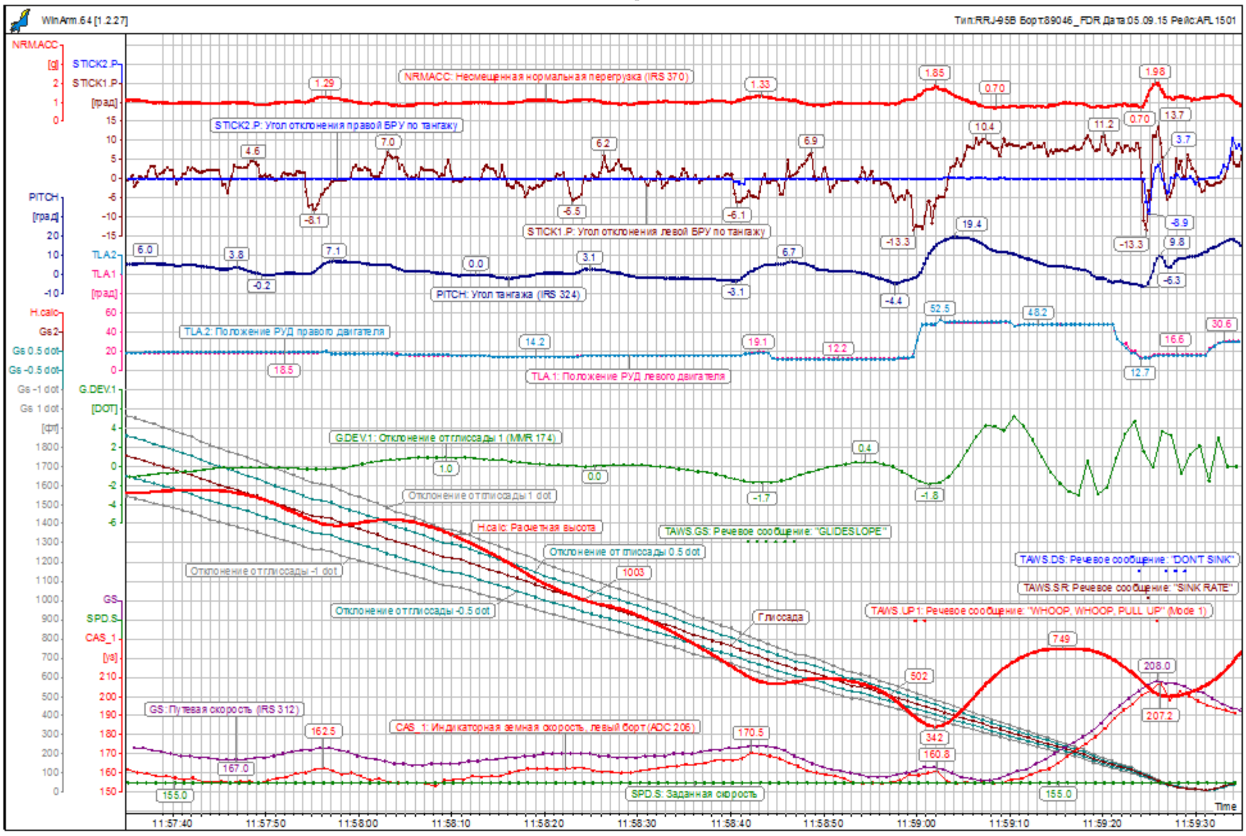


Fig. 77. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the first approach, the pitch channel

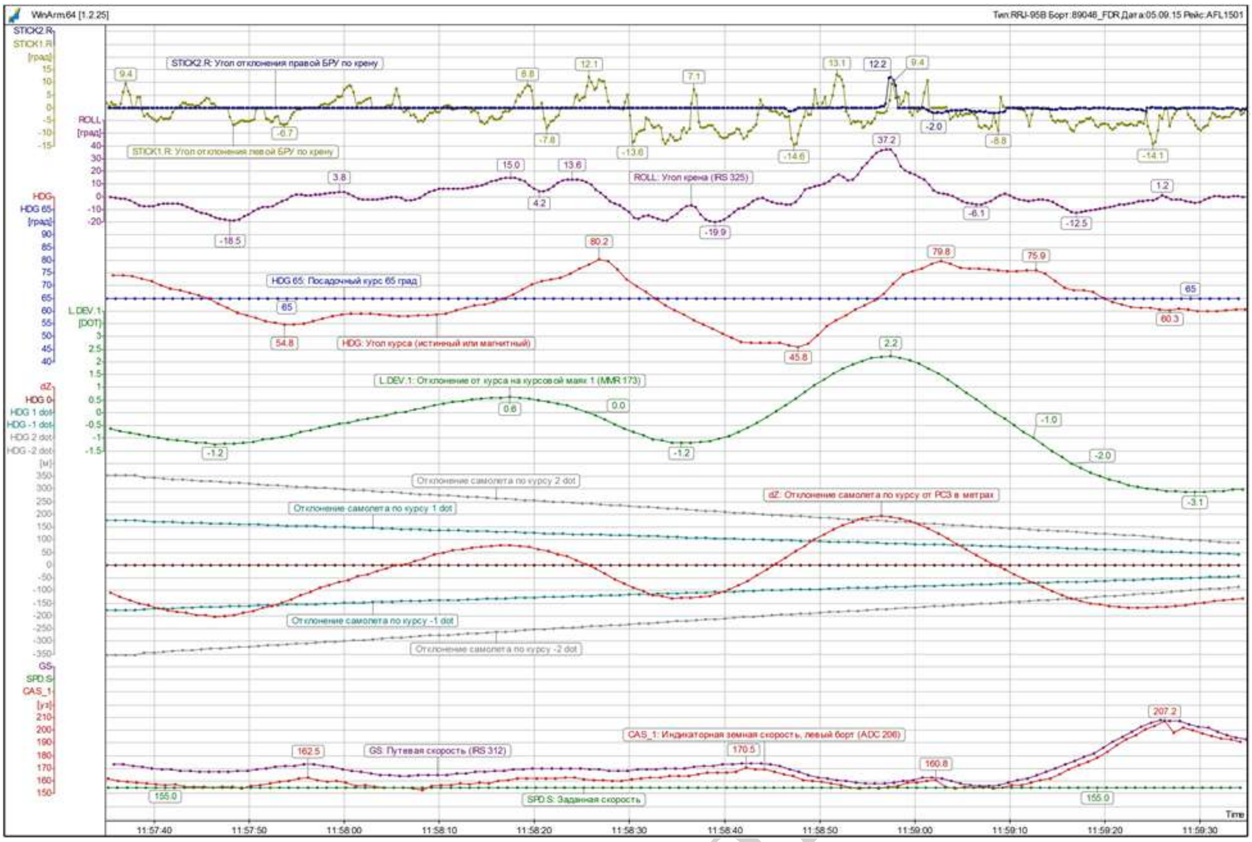


Fig. 78. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the first approach, the lateral channel

The approach was unstabilized. At the altitudes below 1000 ft. the pitch was changing between 4.4° to nose-down and 6.7° to nose-up, the deviations off the glideslope amounted to 1.6 dot down, which at the altitude of about 600 ft. above the RWY threshold resulted in the glideslope warning activation. The crew continued the approach. At the lateral channel the deviations off the extended RWY axis were between 1.2 dot to the left and 2.2 dot to the right, the roll values were close to 20° to the left and 37° to the right. Moreover the dual input was recorded in the roll channel. The go-around was initiated by the crew from the altitude of 380 ft. above the RWY threshold until after the TAWS PULL UP warning activation. In the progress of go-around after the initial climb of about 750 ft. above the RWY threshold there occurred the high-rate descent to the altitude of 500 ft. with the activation of the TAWS DON'T SINK, SINK RATE and PULL UP. Concurrently the dual input in pitch was recorded.

The flight data in the pitch and lateral channels in the progress of the second approach are shown on Fig. 79 and Fig. 80 respectively.

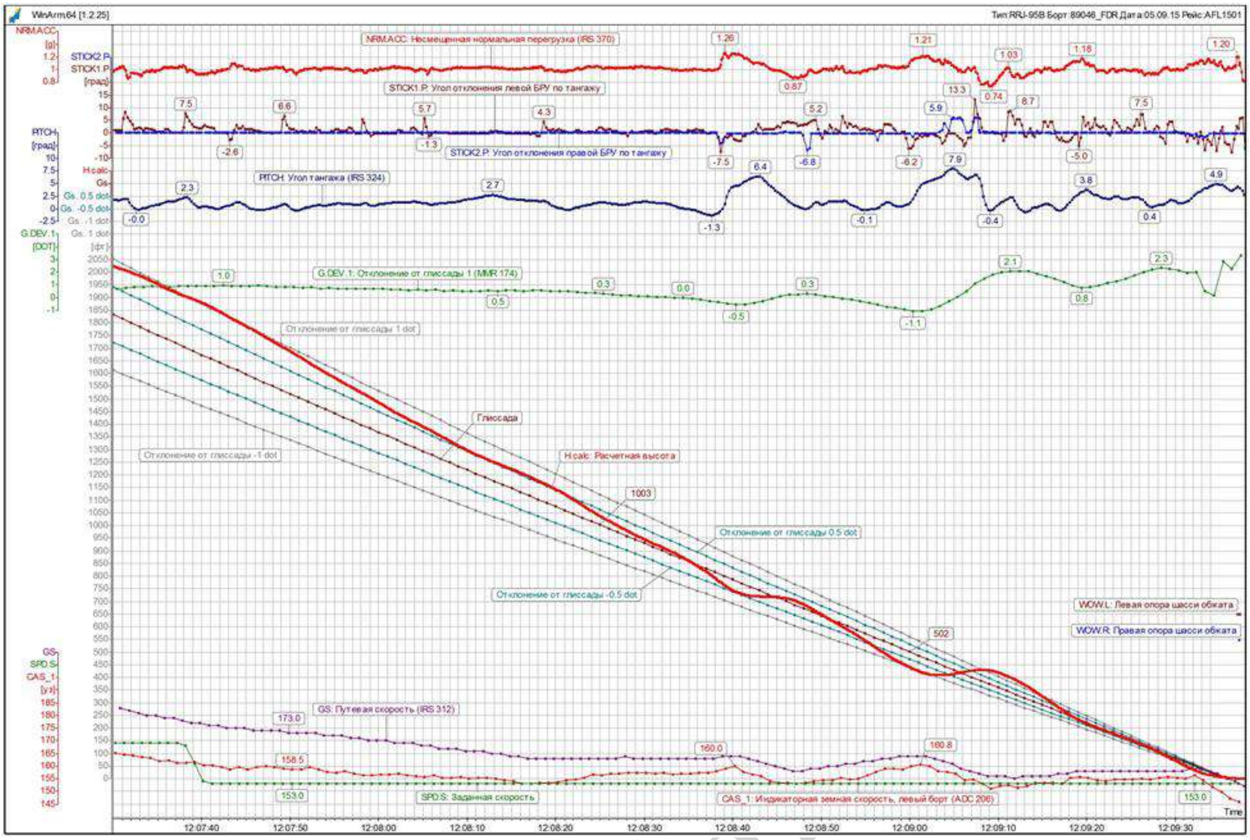


Fig. 79. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the second approach, the pitch channel

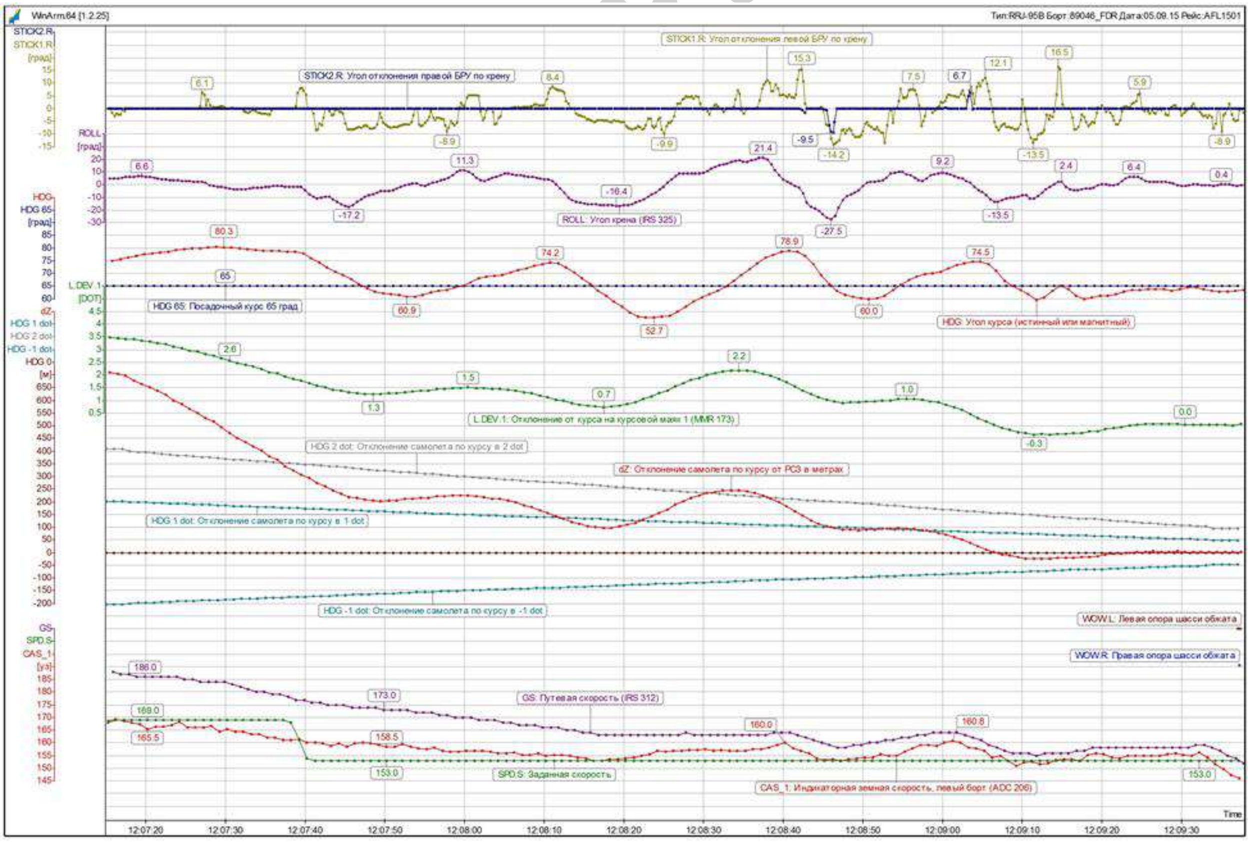


Fig. 80. The RRJ-95 RA-89046 aircraft flight data of 05.09.2015, the second approach, the lateral channel

The second approach was unstabilized as well. At the altitudes below 1000 ft. the pitch was changing between 1.3° to nose-down and 6.4° to nose-up, the deviations off the glideslope reached

1.1 dot down up to 2.1 dot up. In the lateral channel the deviations off the extended RWY axis amounted to up to 2.2 dot to the right, the roll values approached 27° to the left and 21° to the right. Dual input was recorded in both channels. The deviation at touchdown is outlined here above (see Fig. 69). At that, despite all the above mentioned failures, deviations and peculiarities the air incident(s) had not been declared as to this flight[75]. The investigation team has not been communicated whether the operator had undertaken the internal investigation.

The investigation team further analyzed 37 randomly selected flights, having been operated by the PIC, over December 20, 2018 – May 3, 2019, the records of which had been provided by the airline. The primary objective of this analysis was the evaluation of the sustainable skills development of the flare, touchdown and landing roll performance at the PIC together with the identification of hazards, associated with the inconsistency of the actual control inputs and the recommended method, as well as the best (safe) practices. Still this was not intended to be the quantitative or probabilistic assessment of one or another hazard manifestation frequency.

All the flights under discussion had been performed in NORMAL MODE, that is to say the auto trim in pitch had been enabled even with the A/P disengaged. The relative altitude of the A/P disengagement through the flights, subject to analysis, amounted to between 560 and 1920 ft. (the median value of ~1100 ft.), the altitude of the A/T disengagement was equal to between 58 and 1950 ft. (the median value of ~1100 ft.). Equally after the WOW to MLG legs the automatic deployment of speedbrakes had been enabled.

The PIC's piloting technique analysis at the stage from the initiation of flare, detectable as stated hereinbefore at this Section, till the steady WOW to the MLG legs and the NLG lowering allowed identifying the shortcomings and peculiarities as follows:

- the oscillatory alternating sidestick inputs, including beyond neutral to nose-down[76] (Fig. 81 and Fig. 83). Through a number of flights the back sidestick inputs by up to nearly full travel (11°-12°) had been observed;
- the long-term aircraft float above the RWY and the excessively soft touchdown with the MLG wheels spinning, but without the activation of the WOW signals (kiss landing) and automatic speedbrakes deployment. The sidestick input beyond neutral up to the steady WOW to MLG legs (Fig. 82);

[75] As per the formal data in the MAK-IAC database: *«the route straightening at the approach due to the autopilot failure»*.
[76] As shown on Fig. 86, in the neutral position the sidestick features the «preload tightening», which the pilot is to overcome for the sidestick «breakaway» from neutral. In such a way even the minor sidestick inputs cannot occur «randomly».

- the pitch dispersion over a wide range at landing (from 2.7° to nose- up up to 7.7° to nose-up) (Fig. 83 and Fig. 84). Into both flights the piloting technique at flare and landing is far from perfect;
- the performance of landing at significant pitch rate to nose-down (the unsettled pitch value) (Fig. 85), the landing without the WOW signal to MLG legs, the virtually simultaneous activation of the WOW signal to all the three LG legs is noted;
- the excessively abrupt NLG lowering with the considerable acceleration, its consecutive separation and the increase of pitch rate are stated (Fig. 82 and Fig. 85).

The analysis revealed as well that in each and every flight in the progress of the landing roll the sidestick had been kept retained at the full forward position in pitch. In most cases it had been the full forward sidestick input by the PIC at the takeoff run as well.

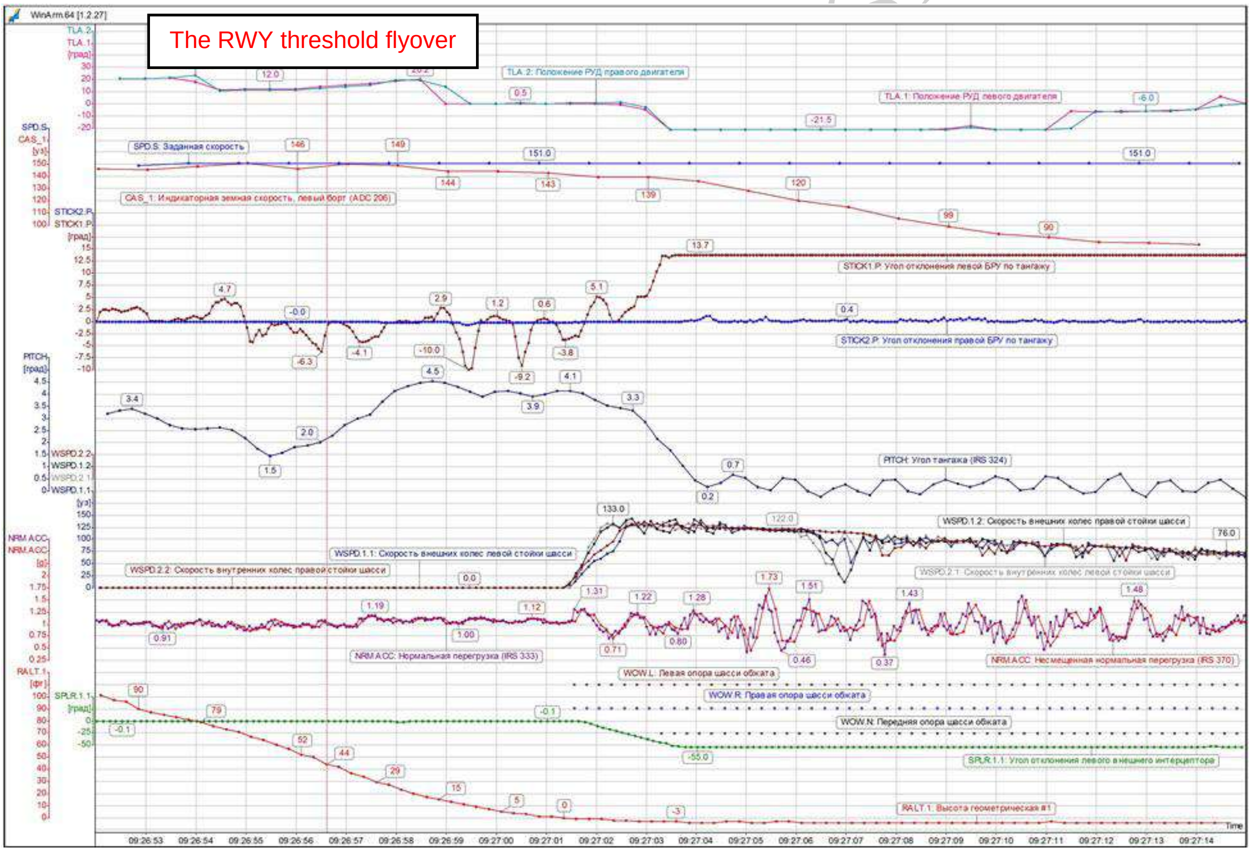


Fig. 81. The flight data at the landing performance by the PIC aboard the RA-89014 aircraft on 27.02.2019

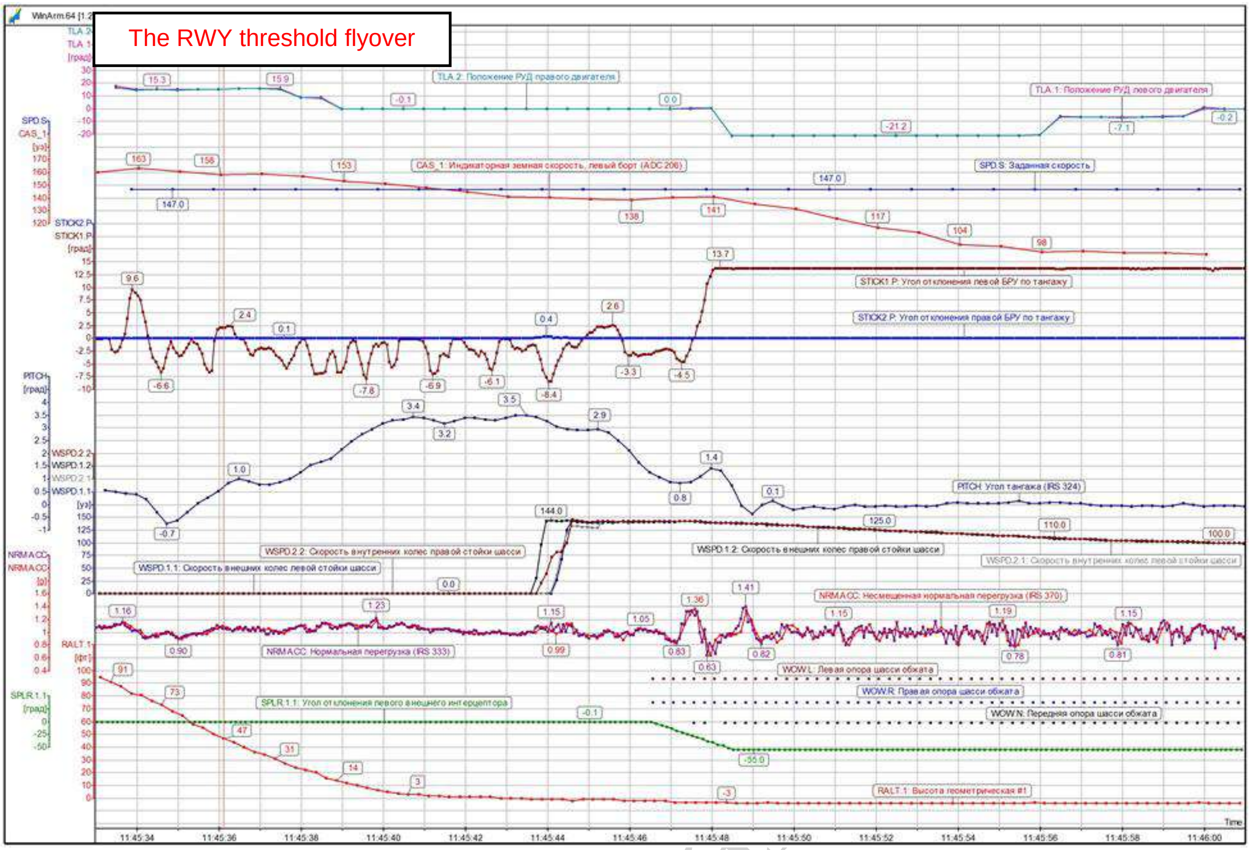


Fig. 82. The flight data at the landing performance by the PIC aboard the RA-89104 aircraft on 01.05.2019

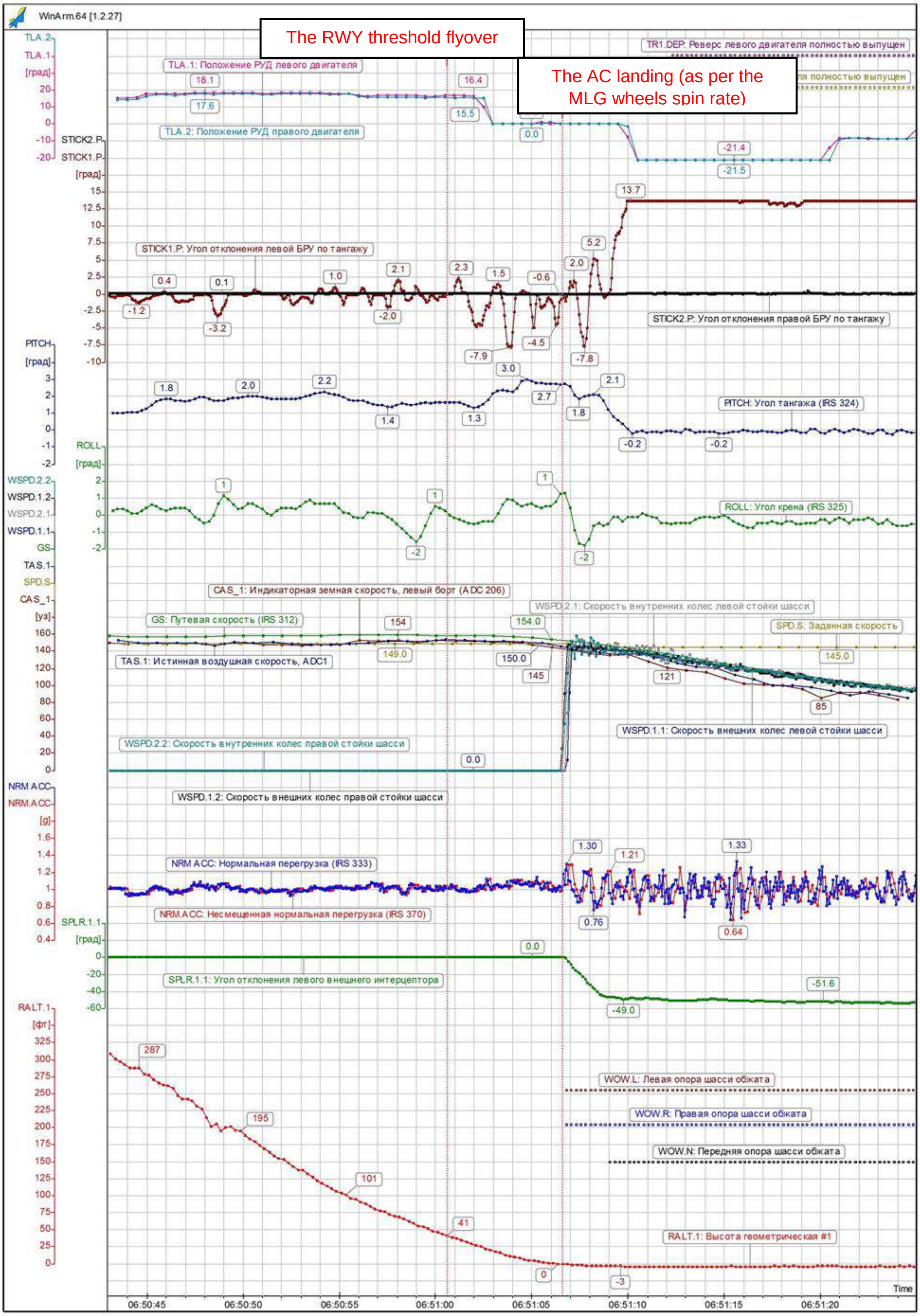


Fig. 83. The flight data at the landing performance by the PIC aboard the RA-89045 aircraft on 29.04.2019

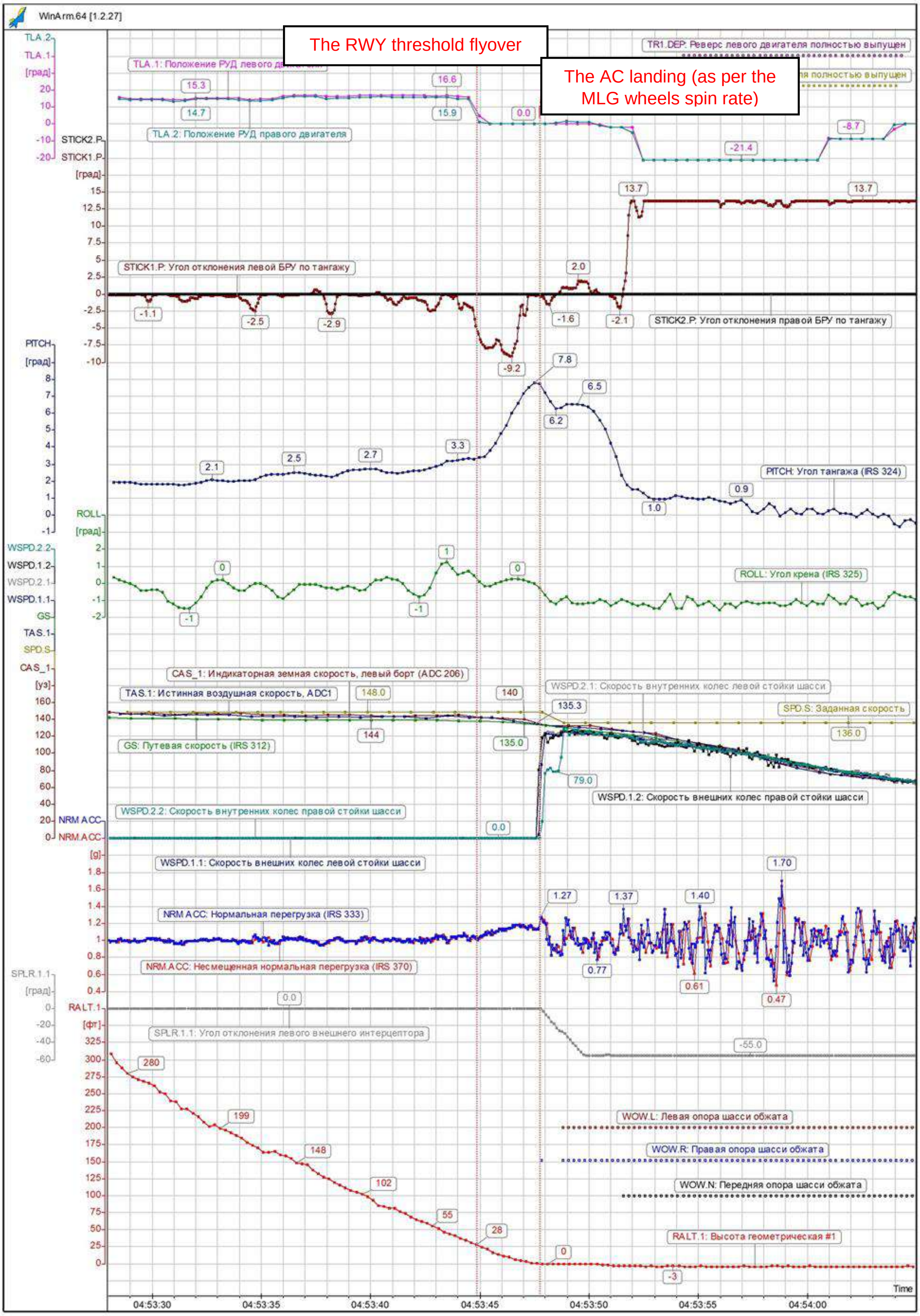


Fig. 84. The flight data at the landing performance by the PIC aboard the RA-89045 aircraft on 05.03.2019

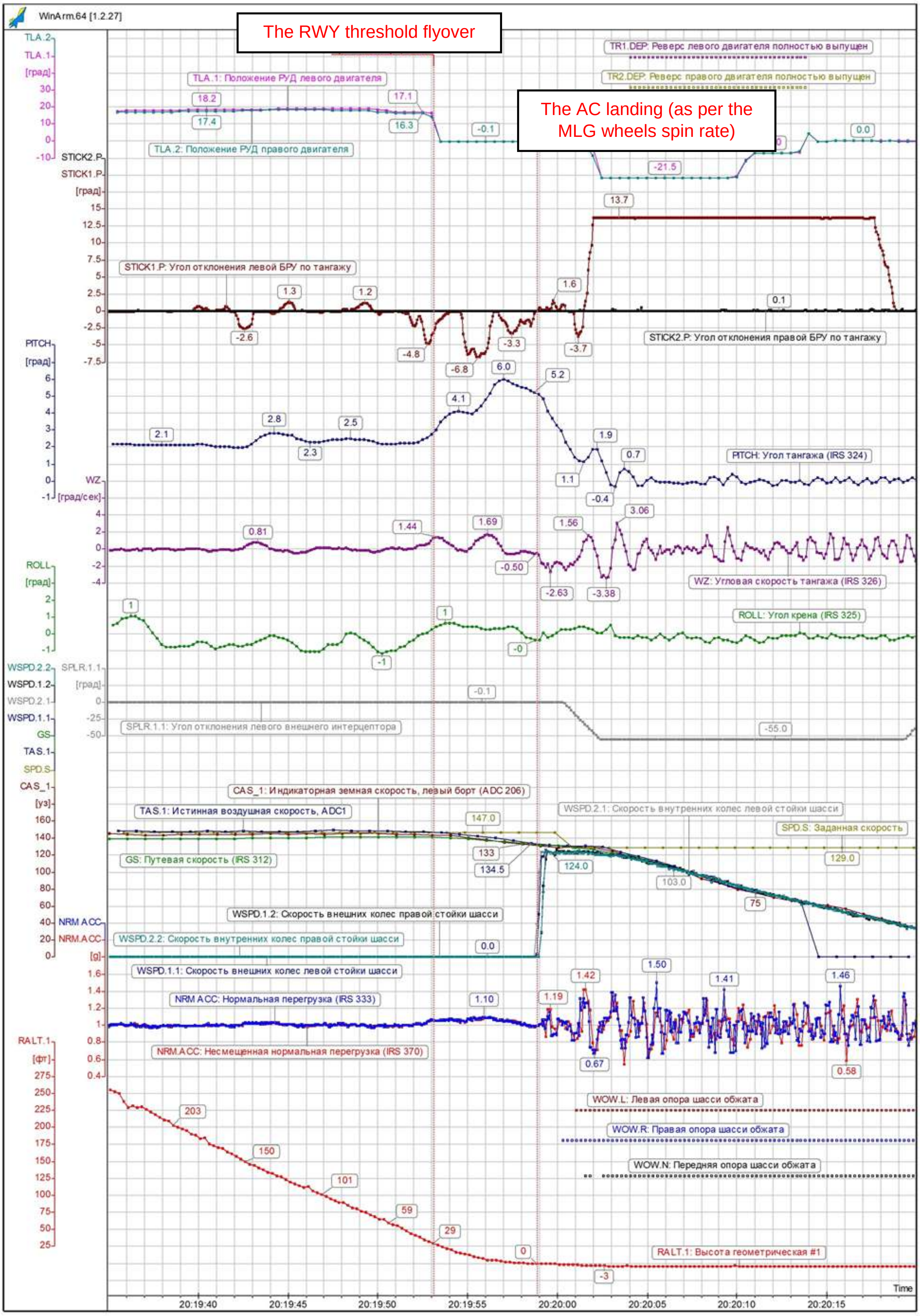


Fig. 85. The flight data at the landing performance by the PIC aboard the RA-89103 aircraft on 12.04.2019

1.16.20. The examination of the structural damage

By the investigation team request the Technical Report «The Analysis of the Structural Damage, Resulting from the Air Accident to the Aeroflot airline RRJ-95B RA-89098 aircraft on 05.05.2019», was drawn up, approved on 18.08.2020. The data out of this examination had been used in drafting Sections 1.3 «Damage to aircraft» and 2.3.3 «Analysis of the structural damage and compliance to the certification requirements» of the Report.

1.16.21 The results of the analysis of the crewmembers psychological testing data[77]

This Section presents the results of the analysis of the crewmembers psychological testing data. The study was carried out by a skilled psychologist with over 25 years of experience in psychodiagnostics (mainly clinical), expert level, teaching and supervision background, as well as the involvement in the forensic expertise and personnel assessment.

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1.16.22 The results of the engineering simulation of the airplane motion

On the air accident investigation team Order, SCAC, JSC had carried out the engineering simulation of the flight that ended up with the accident along with the number of the other scenarios (see the text here below). As the outcome of the activities in question the Technical Report had been drawn up.

The analysis had been done with the use of the RRJ-95 aircraft type design spatial motion simulation software engineering package, which convergence is validated by the flight test data into the entire operational envelope, as set forth in the RRJ0000-RP-002-181 Revision A «On the consistency of the simulation at the SCAC manned flight simulator with the RRJ-95 aircraft actual flights» document, approved by the Vice-President on Design – the SSJ Program chief designer. The aerodynamic, the engines altitude-airspeed performances and the FBWCS engineering model were specified by the results of the certification flight tests.

The aerodynamic performance model is subject to the following documents:

– SSJ0000-TC-015-200 «The updating of the RRJ-95 aircraft aerodynamic performance bank “REV14_scac.mdl” on the results of RSI # RRJ0000-PL-130-2062»;

– The actuators operations package – in compliance to the data by the FBWCS vendor (ECM # RRJ-LL-SU-16-048 of May 12, 2016).

The FBWCS model is in line with the document:

– RRJ0000-RP-002-220» Revision E «The FBWCS control laws reference model of the DV5.02 version, compliant to the document «The engineering description of the FBWCS control laws to the RRJ family aircraft to integrate in the PFCU, ACE and MACE processors. The FBWCS software version DV5.02».

The SaM-1461S17 propulsion powerplant model is consistent with the reference engineering model by the propulsion powerplant vendor (PowerJet S.A.).

The mentioned configuration of the aerodynamic and the engines altitude-airspeed performances and the FBWCS algorithms is compatible with the RRJ-95B MSN95135 RA-89098 aircraft, having been involved in the air accident.

1.16.22.1 The features of the sidestick feel and damping in pitch channel

When designing the RRJ-95 airplane flight control system with the sidesticks the activities were arranged on the selection of the sidestick ergonomic and feel features taking into account the characteristics of the airplane pitch and lateral stability and controllability into the entire operational envelope.

As per the estimates by the SCAC, JSC test pilots, as well as by the test pilots to the IAC AR, Russian Federation AR and EASA, having been obtained at the experiments at the piloted simulator and confirmed by the flight tests, the actually implemented features of the sidestick feel, damping and ergonomics are acknowledged optimal in terms of the manual control in all the FBWCS operational modes.

The essential feel features of the sidestick in pitch channel[78] are the following:

The characteristic of the static force

Definition: the characteristic of the static force is determined as the force curve, plotted by the values of the force, applied at the back and forward input of the handle with the negligible rate - depending on the sidestick position.

Inherently the static force characteristic does not imply the damping and friction forces.

The static force characteristic of the sidestick along the pitch axis is within the limits, indicated on Fig. 86.

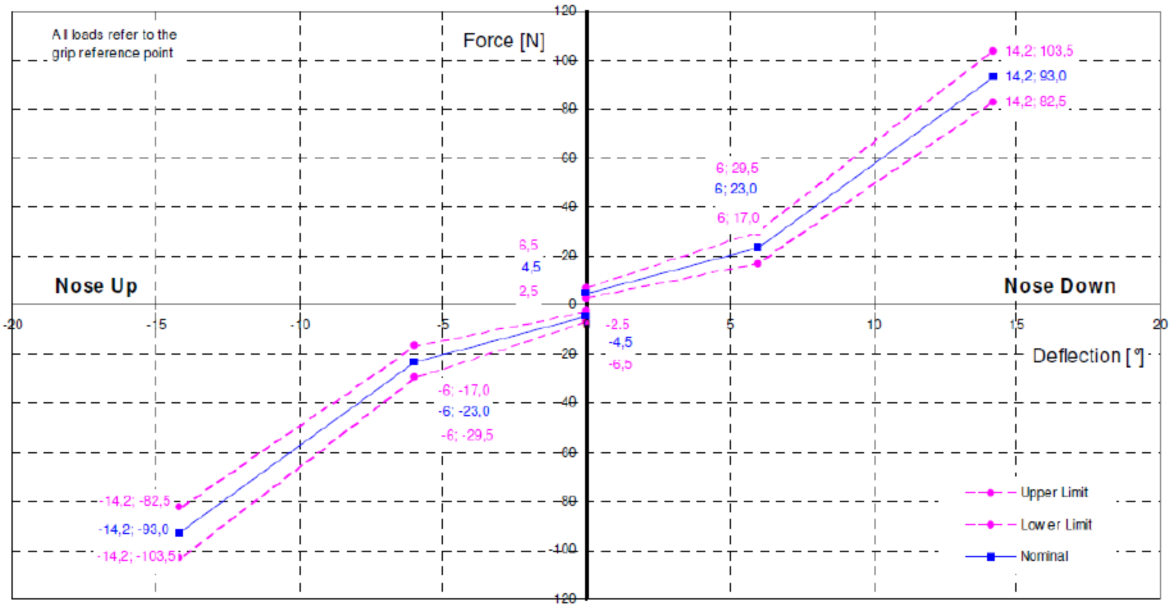

Fig. 86. The sidestick static characteristic in pitch

The characteristic of the friction force

Definition: the (dry) friction force is determined as the difference between the actual static force and the actual measured force (depending on position) applied by the handle back and forward input at a constant speed.

By its nature, the friction force does not imply the damping force.

The sidestick friction force does not exceed 0.04 kg.

The characteristic of the damping force

Definition: the damping force is determined as the force constituent, applied on the handle, proportional to the lever input rate.

Inherently the damping force does not imply the friction force and is always oriented against the lever motion.

[78] The FBWCS operational mode does not affect the feel characteristics.

The damping ratio is determined as the ratio of the damping force to the rate of the lever turn.

Along the pitch axis the damping force lies within a range of 0.03 – 0.04 kg/(deg·sec^{-1}).

1.16.22.2 On the lags in the pitch control channel

Fig. 87 – Fig. 90 present the transient response plots of the sidestick – elevator path of the open-loop system at the input harmonic signal (of the 0.3 Hz and 1 Hz) in the linear region (with the half-travel deflection amplitude of the sidestick) and in the non-linear region (with the full travel deflection amplitude of the sidestick) of the actuators operation. The transient responses are given for the FBWCS DIRECT MODE and NORMAL MODE at the VCAS = 170 kt. As for the NORMAL MODE the dependencies are represented for two true altitudes of above and below 50 ft.[79]. In the figures the blue color shows the sidestick deflection in degrees, whereas the red color stands for the elevator response (in degrees as well): the solid line is for DIRECT MODE, the dashed line is for NORMAL MODE, H_{AGL}=15 ft., the dotted line stands for NORMAL MODE, H_{AGL}=60 ft.

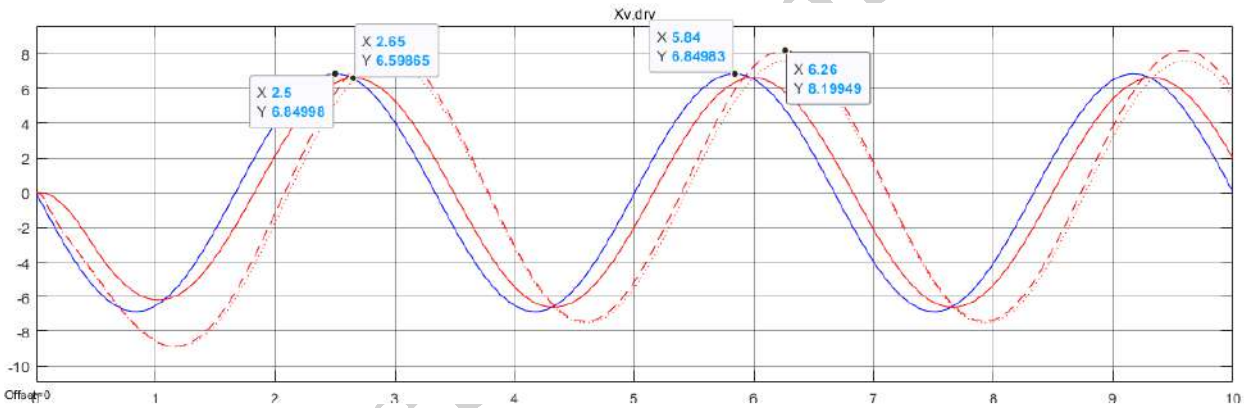

Fig. 87. DM-NM, sidestick=6.85^0 (50% of travel), frequency 0.3 Hz, τ(DM) ≈ 0.15 sec, τ(NM) ≈ 0.42 sec

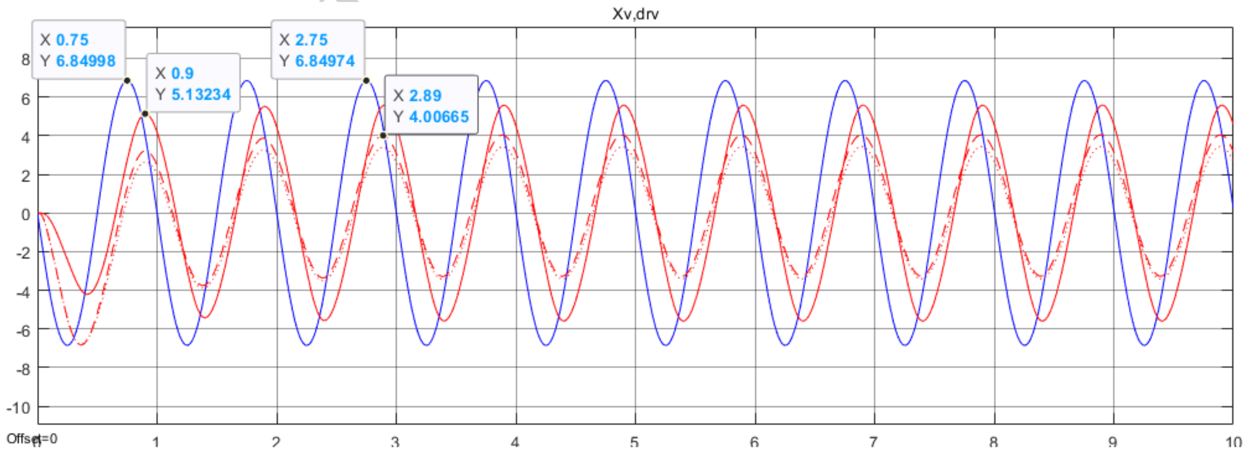

Fig. 88. DM-NM, sidestick=6.85^0 (50% of travel), frequency 1 Hz, τ(DM) ≈ 0.15 sec, τ(NM) ≈ 0.14 sec

[79] Below the true altitude of 50 feet there is a change of the control law in pitch channel at the FBWCS NORMAL MODE (for more details see the text of the Report below).

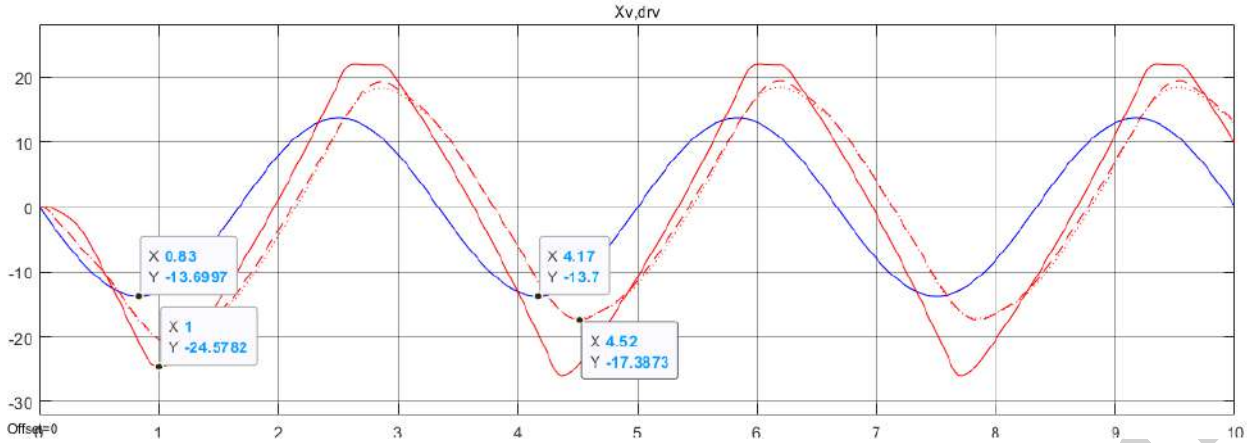

Fig. 89. DM-NM, sidestick=13.7^0 (100% of travel), frequency 0.3 Hz, τ(DM) ≈ 0.17 sec, τ(NM) ≈ 0.35 sec

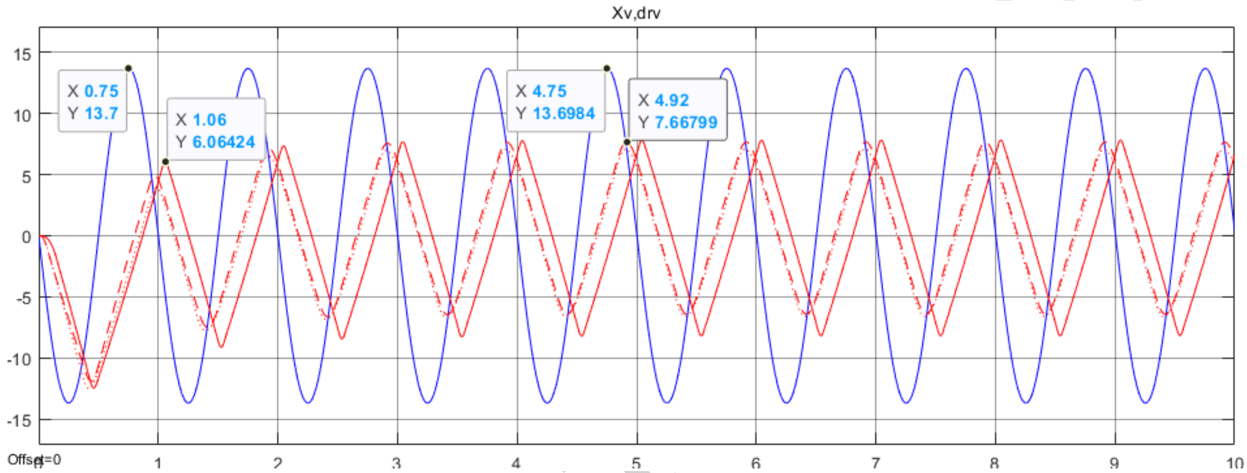

Fig. 90. DM-NM, sidestick=13.7^0 (100% of travel), frequency 1 Hz, τ(DM) ≈ 0.31 sec., τ(NM) ≈ 0.17 sec.

The presented plots are the evidence that at the harmonic deflection of the sidestick by 50 % of travel the elevator response equivalent lag in NM or DM is either virtually the same (at the 1 Hz frequency), or the lag is greater in NM (at the 0.3 Hz frequency). At the harmonic deflection of the sidestick by 100 % of travel in NM the lag is greater at the 0.3 Hz frequency and less (by 0.14 sec) at the 1 Hz frequency.

In the linear region of the actuator operation (before reaching the limits of the actuator rod deflection rate), the total lag of the sidestick - elevator path is made up of the lags, introduced by the dynamic links of the control law and the dynamic links of the elevator actuator. At that the phase lag is determined by the sidestick deflection frequency - the more is the sidestick deflection frequency, the more is the phase lag.

In the non-linear region of the actuator operation, in the case of reaching the limit on the actuator rod rate, which had been the occurrence in the flight that ended up with the accident, at the sharp deflection of the sidestick from stop to stop by the pilot, the total lag time is significantly affected by the limitation of the actuator deflection rate as opposed to the command signal change rate (the sidestick input rate).

At the design of the RRJ-95B airplane the following requirements to the elevator actuators[80] are admitted:

#	The characteristic title	Dimensionality	Value
1	Maximum angular rate of the elevator surfaces deflection with no external load	deg/sec	30
2	The actuator sensitivity threshold not more than	mm	0.15
3	The phase shift not more than: at the 0,5 Hz frequency at the amplitude of 0.5(±0,05) mm 1.0(±0,1) mm at the1 Hz frequency at the amplitude of 0,5(±0,05) mm 1.0 (±0,1) mm	deg	 -25 -15 -35 -25

At the step sidestick deflection with its keeping retained the lag time is totally determined by the actuator maximum rate and the more is the amplitude of the input step deflection, the more is the lag time. For instance Fig. 91 and Fig. 92 show the sidestick – elevator path transient responses plots in an open loop for the FBWCS DIRECT MODE (VCAS = 170 kt) at the sidestick input by the half-travel and at the maximum deflection. As for these figures the blue color shows the sidestick deflection in degrees, whereas the red color stands for the elevator response (in degrees as well).

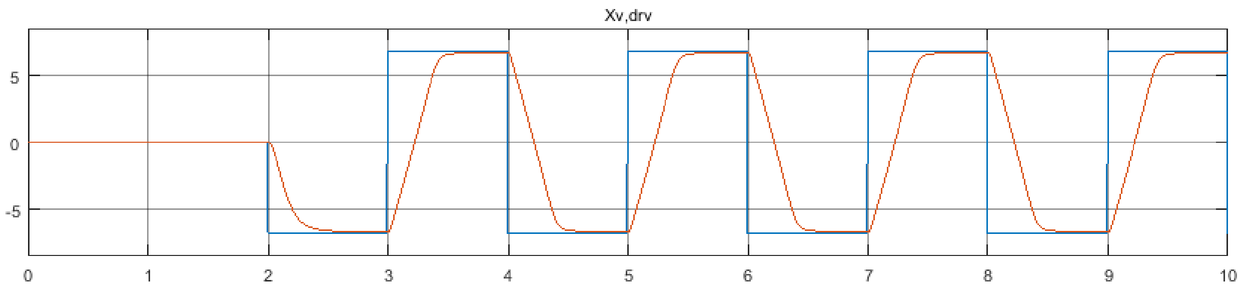

Fig. 91. DM, sidestick=6.8^0(50% of travel), τ ≈ 0.44 sec

[80] As explained by the aircraft designer, these requirements correlate well with the statistical data on the other modern commercial airplanes actuators (see Fig. 171 of the Report as well).

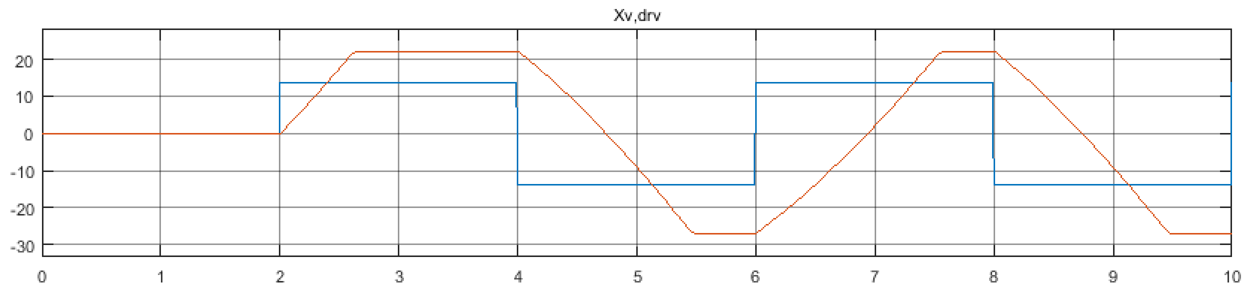

Fig. 92. DM, sidestick=13.7^0(100% of travel), τ ≈ 1.5 sec.

To describe the dynamic process characteristics in the sidestick – pitch attitude closed loop, it is important to understand the physical basis of this process. The in-flight deflection of the elevators generates the motion of the aircraft around the center of mass, which is of an integral nature with the associated phase lags.

So thus, at the deflection of the elevator, for instance, in the conditions of the balanced straight motion the pitch moment is generated, which to the first approximation can be determined by the dependence as follows:

$$Mz = Mz^{\alpha}\Delta\alpha + Mz^{\delta}\delta + Mz^{\omega}(\omega_z + d\alpha/dt),$$

where:

$\Delta\alpha$ – the AOA deviation off the trimmed value;

δ – the elevator deflection;

ωz – the pitch angular rate;

Mz^{α}, Mz^{δ}, Mz^{ω} – the respective derivatives of the aerodynamic moment.

The indicated dependence implies that if the perturbed motion is small, then the aerodynamic moment is almost completely determined by the angle of the elevator deflection.

The aerodynamic moment, generated by the elevator deflection causes the development of the angular acceleration of the airplane, which is determined by the following expression:

dωz/dt = Mz/Iz,

where Iz – the pitch inertia (against the Z/lateral axis).

The equation implies that at the change of the aerodynamic moment (the elevator deflection) the angular acceleration changes (is generated) with virtually no lag. The magnitude of the angular acceleration itself is inversely proportional to the pitch inertia – the less is the latter, the more is the angular acceleration.

The angular rate is an integral of the angular acceleration, which, due to its properties, introduces a phase lag in the response of the angular rate to the change in the angular acceleration.

The pitch attitude is an integral as well, but of the pitch angular rate: dυ/dt = ωz. Just as in the case of angular acceleration, at the change of the angular rate the integral introduces a phase lag in the pitch response of the airplane.

Hence the lag in the sidestick – pitch attitude path is determined by the sidestick –elevator path characteristics of the specific aircraft type and by the physical laws of motion. With the laws of physics the total exclusion of lag is not feasible.

To illustrate the phase lags, introduced by the integral dependencies of the angular motion equations in the pitch channel the Fig. 93 and Fig. 94 present the transient responses of the airplane angular motion at the harmonic deflection of the sidestick by half-travel at the 0.3 Hz frequency at the frozen point: G = 42500 kg, Iz = 1490000 km*m^2, X_{CG} = 25 % MAC, FLAPS 3, VCAS=170 kt. The transient responses are given for two FBWCS operational modes (the solid curves for DM, the dashed curves for NM, the blue color stands for the first parameter in the region title, the red color does for the second parameter in the region title) and for two true altitudes (9 ft and 60 ft.).

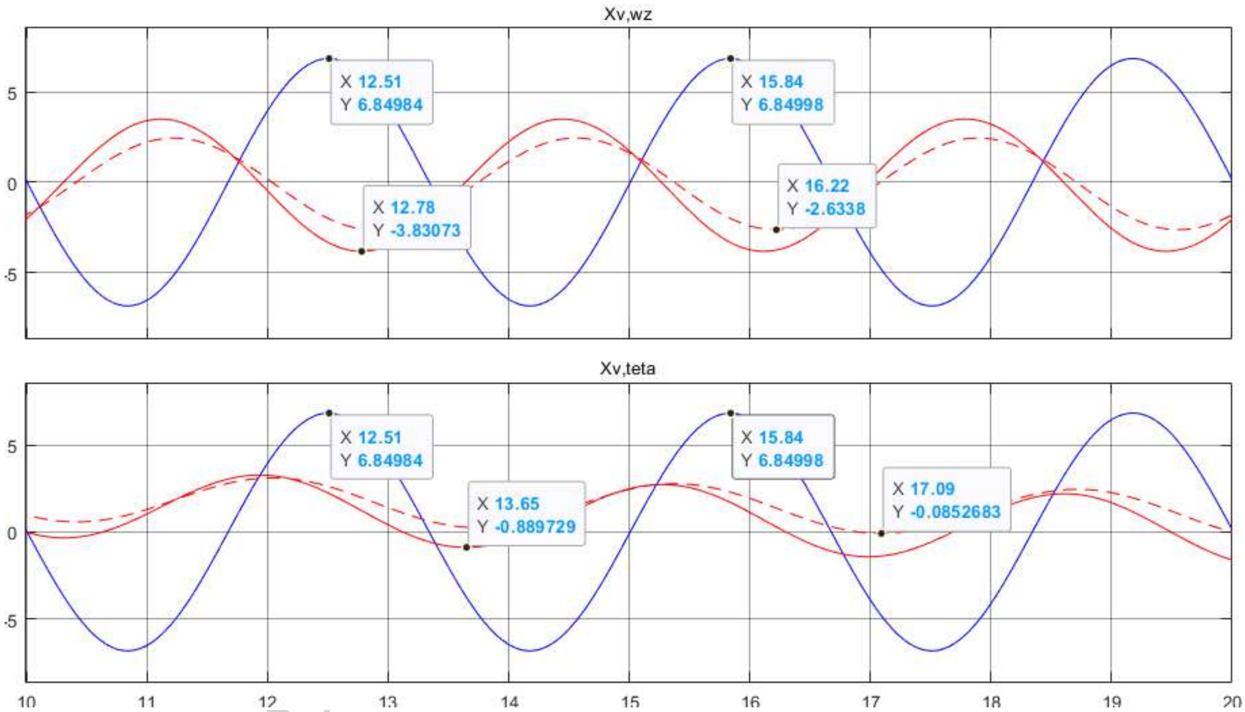

Fig. 93. The angular motion transient responses at the harmonic half-travel sidestick deflection, DM-NM, H_{AGL} = 9 ft.

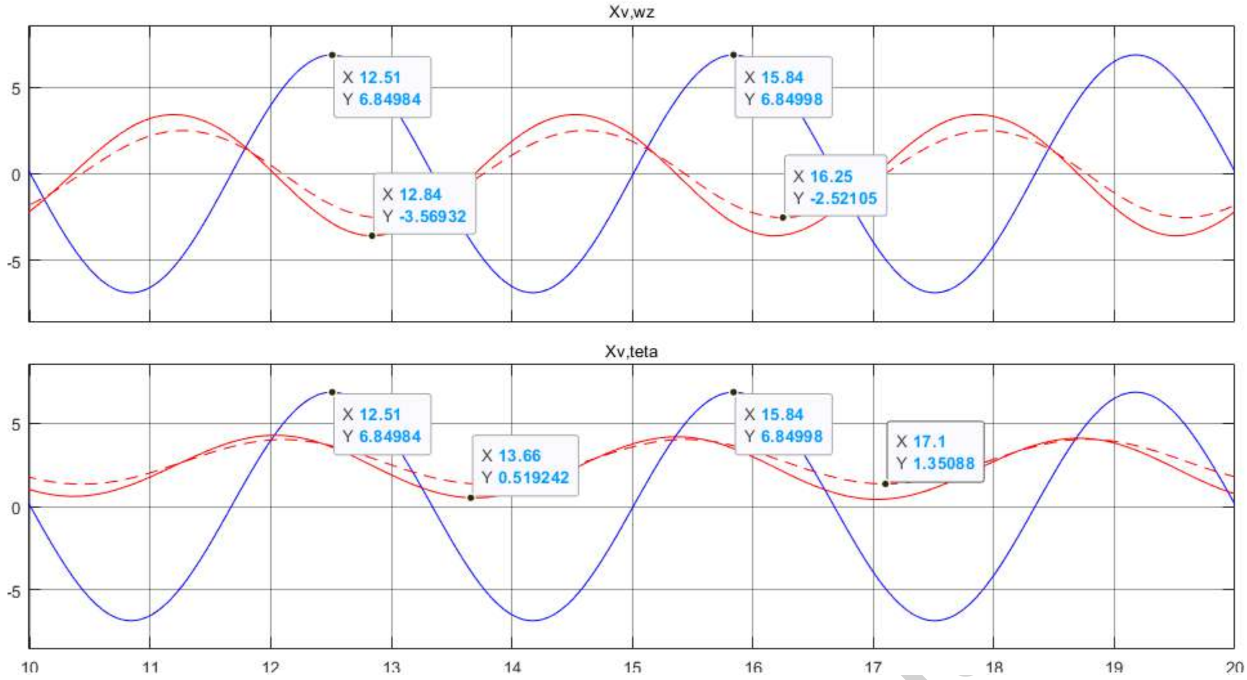

Fig. 94. The angular motion transient responses at the harmonic half-travel sidestick deflection, the DM-NM mode, H_{AGL} = 60 ft.

The upper part of each of the figures shows the sidestick – pitch angular rate («Xv, wz»). As for DIRECT MODE the lag is equal to ~ 0.3 sec, for NORMAL MODE is of ~ 0.4 sec. The magnitude of the lag is largely independent of the altitude of flight.

The lower part of each of the figures shows the sidestick – pitch attitude path («Xv, teta»). As for DIRECT MODE the lag is equal to ~ 1.15 sec, for NORMAL MODE is of ~ 1.25 sec. The magnitude of the lag is largely independent of the altitude.

1.16.22.3 The operation of the sidestick – elevator path of the RRJ-95B RA-89098 aircraft on the landing on May 05, 2019

Fig. 95 presents the results of the simulation of the sidestick – elevator path at the landing into the RRJ-95B aircraft flight that ended up with the accident on May 05, 2019 taking into account the dynamics of the aircraft motion.

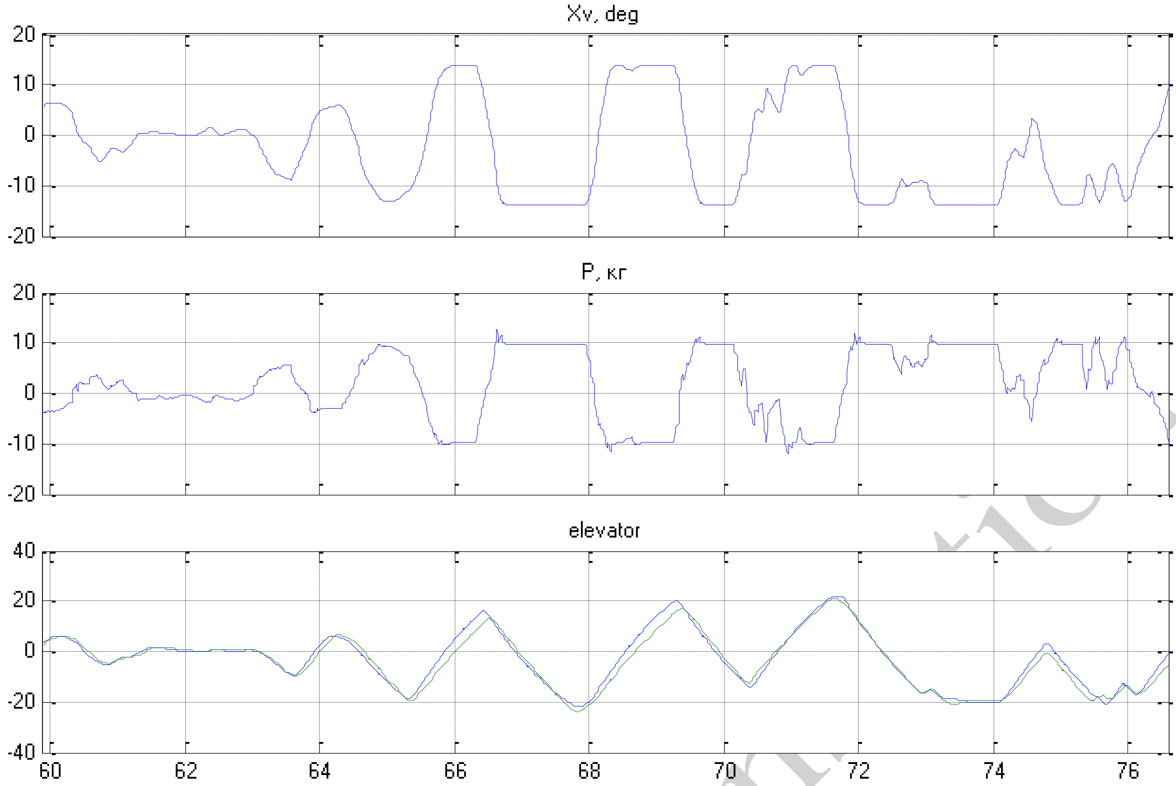

Fig. 95. The parameters of the sidestick-elevator path of the RRJ-95B RA-89098 aircraft at the landing on May 05, 2019[81]

The figure shows the parameters as follows: Xv, deg – the sidestick pitch input as per the FDR data, deg; P, kg (the plus sign stands for the back input) – the estimated sidestick pressure under the feel rated performance; elevator – the elevator deflection angle, deg: the blue curve – the results of the simulation, the green line – the FDR record.

These plots are the evidence that the pilot had exercised the step-by-step sidestick inputs from stop to stop at the final leg of the landing. At that the pressure in pitch on the lever taking into account the sidestick dampers operation had reached 12 kgf. The elevator surfaces deflected with the highest possible rate of the actuators.

The presented results of the simulation of the sidestick – elevator path demonstrate the satisfactory convergence with the FDR records, only at some segments there is a slight (< 0.2 sec) deviation of the recorded value against the estimated one, that allows making the conclusion on the consistency of the RRJ-95B RA-89098 airplane flight control system behavior at the landing into the flight of May 5, 2019 that ended up with the accident with the type design sidestick – elevator path reference model in use.

Fig. 96 presents the results of the simulation of the sidestick – pitch attitude path angular motion into the RRJ-95B RA-89098 flight environment.

[81] This and the rest of the plots in this Section are presented as a function of relative time.

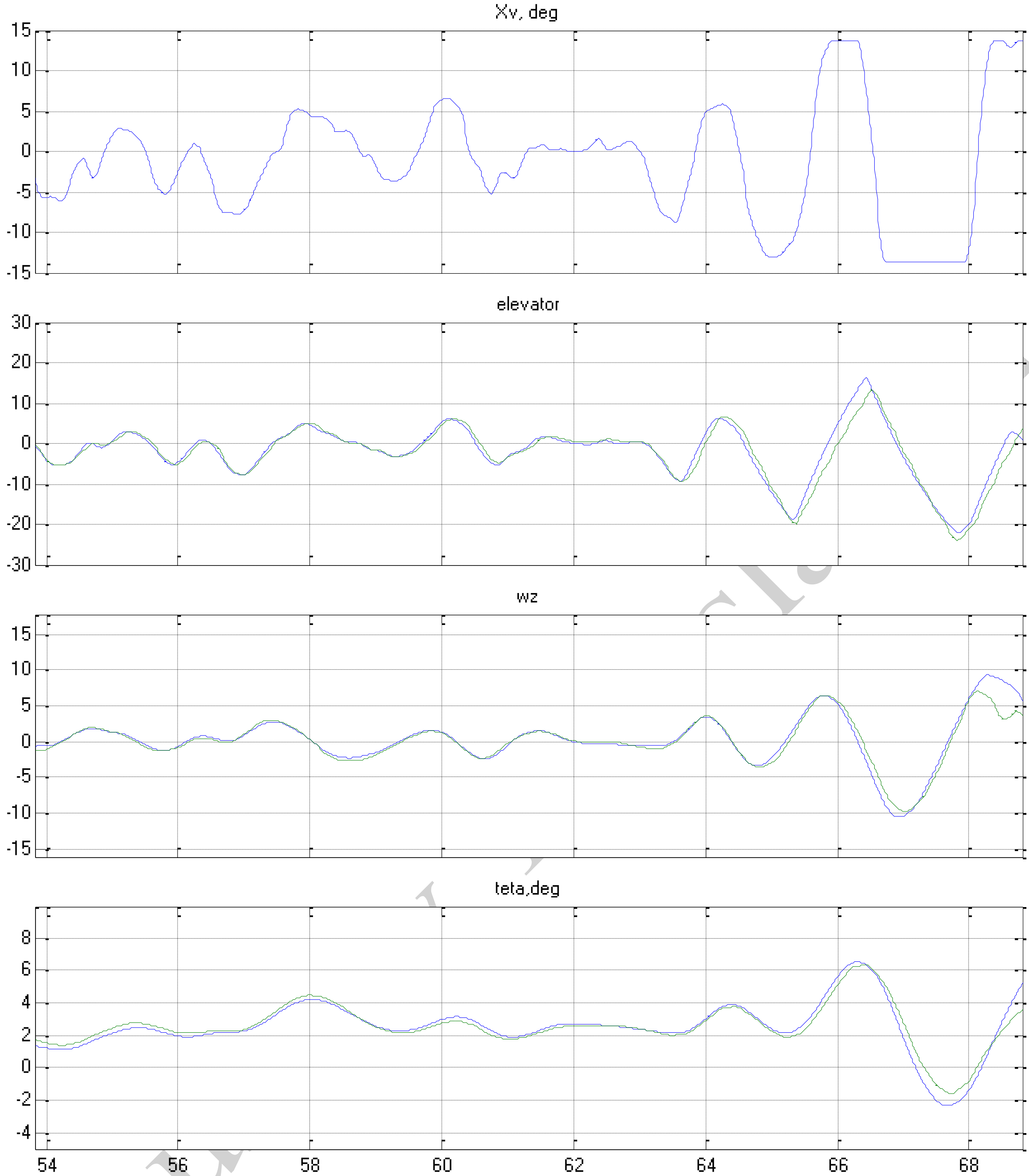

Fig. 96. The results of the simulation of the RRJ-95B RA-89098 aircraft pitch motion at the landing on May 05, 2019

The figure shows the parameters as follows: Xv, deg – the sidestick input as per the FDR record, deg; elevator – the elevator deflection angle, deg: the blue line – the results of the simulation, the green line – the FDR record; wz – pitch angular rate, deg/sec.: the blue line – the results of the simulation, the green line – the FDR record; teta – the pitch attitude, deg: the blue line – the results of the simulation, the green line – the FDR record.

The presented results of the sidestick – pitch attitude path simulation demonstrate the satisfactory convergence with the FDR records that allows making the conclusion on the consistency of the RRJ-95 RA-89098 aircraft at the landing into the flight of May 5, 2019 that ended up with the accident with the sidestick – pitch attitude path reference model in use.

1.16.22.4 The estimation of the actual wind disturbances

The evaluation of the wind disturbances along the landing path was carried out in two steps. As for the first stage from the relative altitude of 400 m (1310 ft), Trel = 0 sec and down to the altitude of 124 m (406 ft), Trel = 80 sec the simulation has been carried out in the mode of the automatic stabilization with the set parameters of the flight by glideslope. At this step the automatic stabilization law parameters were selected to ensure the satisfactory convergence of the sidestick inputs and the altitude with the corresponding values of the FDR record. The approach of the kind made it possible at the next step to estimate the wind velocity by selecting its value to ensure the convergence of the simulated values of the ground and indicated airspeeds with the corresponding values of the FDR record.

At the second stage from the altitude of 124 m (406 ft.), Trel = 80 sec. and to the touchdown due to the distinct non-linear nature of the descent path the simulation was carried out by setting the control inputs in the FBWCS control loop (through the sidestick inputs) and the powerplant (through the TL inputs) as per the FDR record.

Fig. 97 demonstrates the results of the simulation, the blue curve represents the estimation of the horizontal wind velocity (in m/sec.), established by the simulation according to the method, described here above, the green curve is for the estimation of the same value as per the FDR record. As for the plot the accepted sign convention is of «-» for headwind, «+» for tailwind.

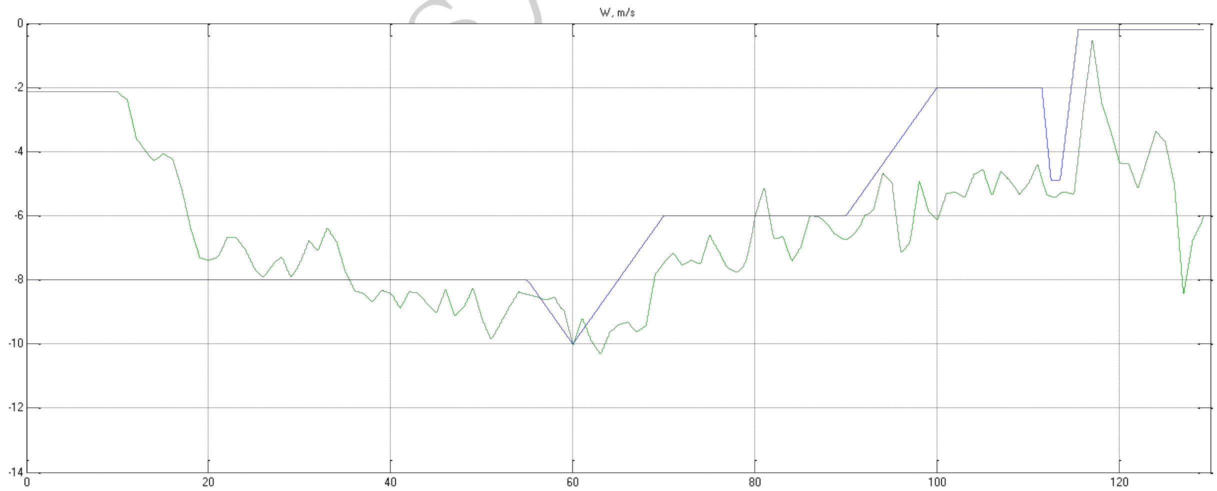

Fig. 97. The comparison of the estimated and recorded horizontal wind component

The estimation of the wind velocity is the evidence that into the flight under consideration it had been the effect of the headwind component that may be split in several spots:

1. from the altitude of 400 m (Trel = 0) to an altitude of 217 m (Trel = 55 sec), the average velocity of the headwind component was 8 m/s;

2. from the altitude of 217 m (Trel = 55 sec.) to the altitude of 162 m (Trel = 70 sec), a spot was observed where the velocity of the headwind component first (in 5 sec) increased up to 10 m/s, and then (within 10 sec.) decreased down to 6 m/s;

3. from the altitude of 162 m (Trel = 70 sec) to the altitude of 91 m (Trel = 90 sec), the average velocity of the headwind component was 6 m/s;

4. from the altitude of 91 m (Trel = 90 sec) to the altitude of 50 m (Trel = 100 sec), the velocity of the headwind component decreased to 2 m/s and remained constant down to the altitude of 8 m (Trel = 111.5 sec.);

5. from the altitude of 8 m (Trel = 111.5 sec.) the wind microburst was observed, in which the headwind component first, within 1 second, sharply increased to ~ 5 m/s (Trel = 112.5 sec), and then, from the point of time of Trel = 113.5 sec., in 2 seconds it decreased to almost zero.

On average these plots demonstrate a good convergence of the wind velocity headwind component estimation with the FDR records, except for the presence of the wind microburst on spot 5 that was established at the simulation.

Into the further simulation the estimation of the headwind component velocity, obtained from the results of the simulation, was taken as the set wind disturbances.

1.16.22.5 The analysis of the model convergence with the airplane dynamics at the final leg of the landing

To evaluate the degree of consistency between the motion model and the actual dynamics of the aircraft in the landing mode the comparative engineering simulation had been carried out as to the final leg of the flight. At the engineering simulation there had been the task set to sync the aircraft first touchdown of the RWY surface by the simulation and the FDR record. Fig. 98 and Fig. 99 present the results of the simulation.

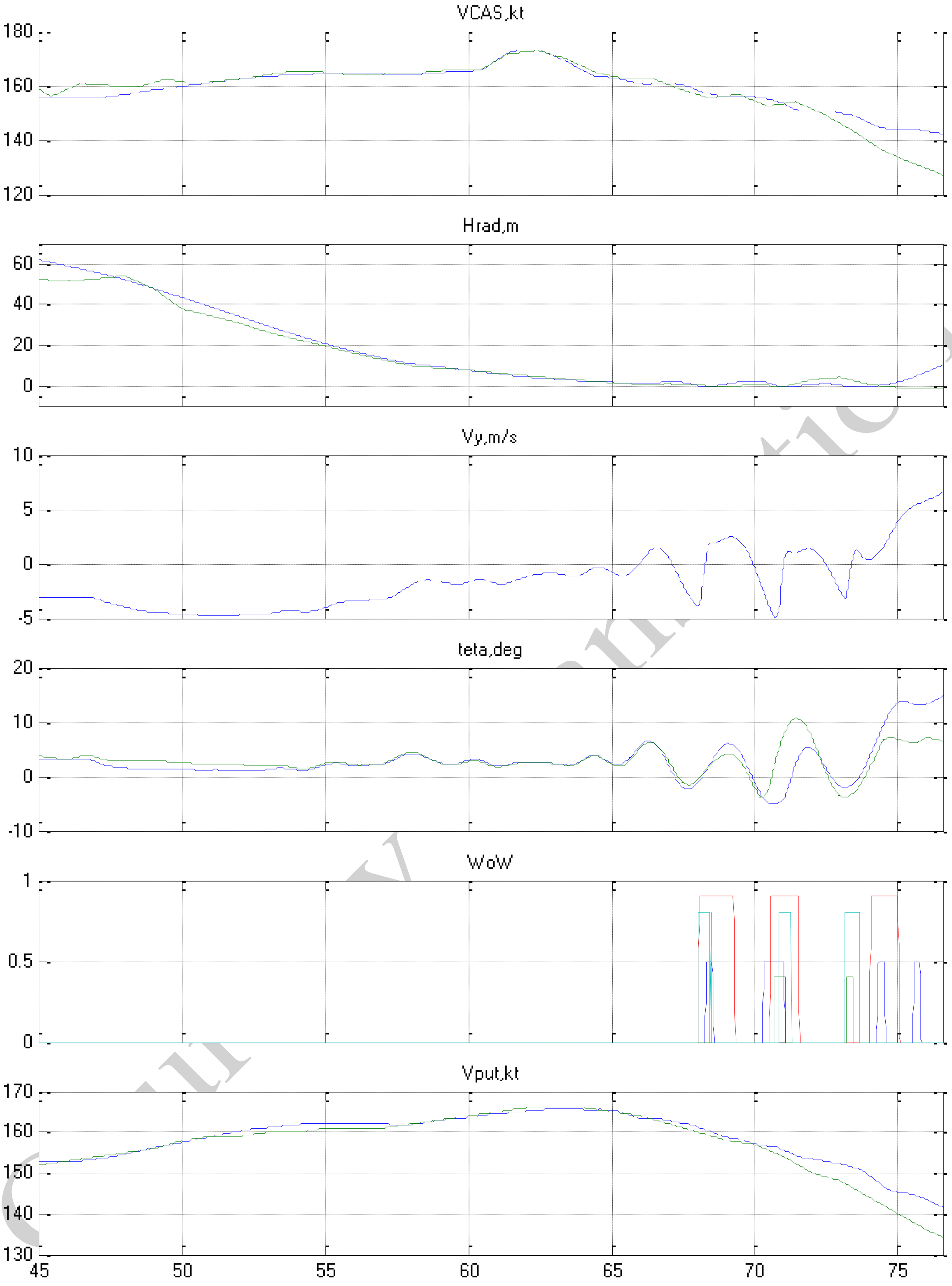

Fig. 98. The comparison of the flight data records and the results of the simulation. The flight path parameters

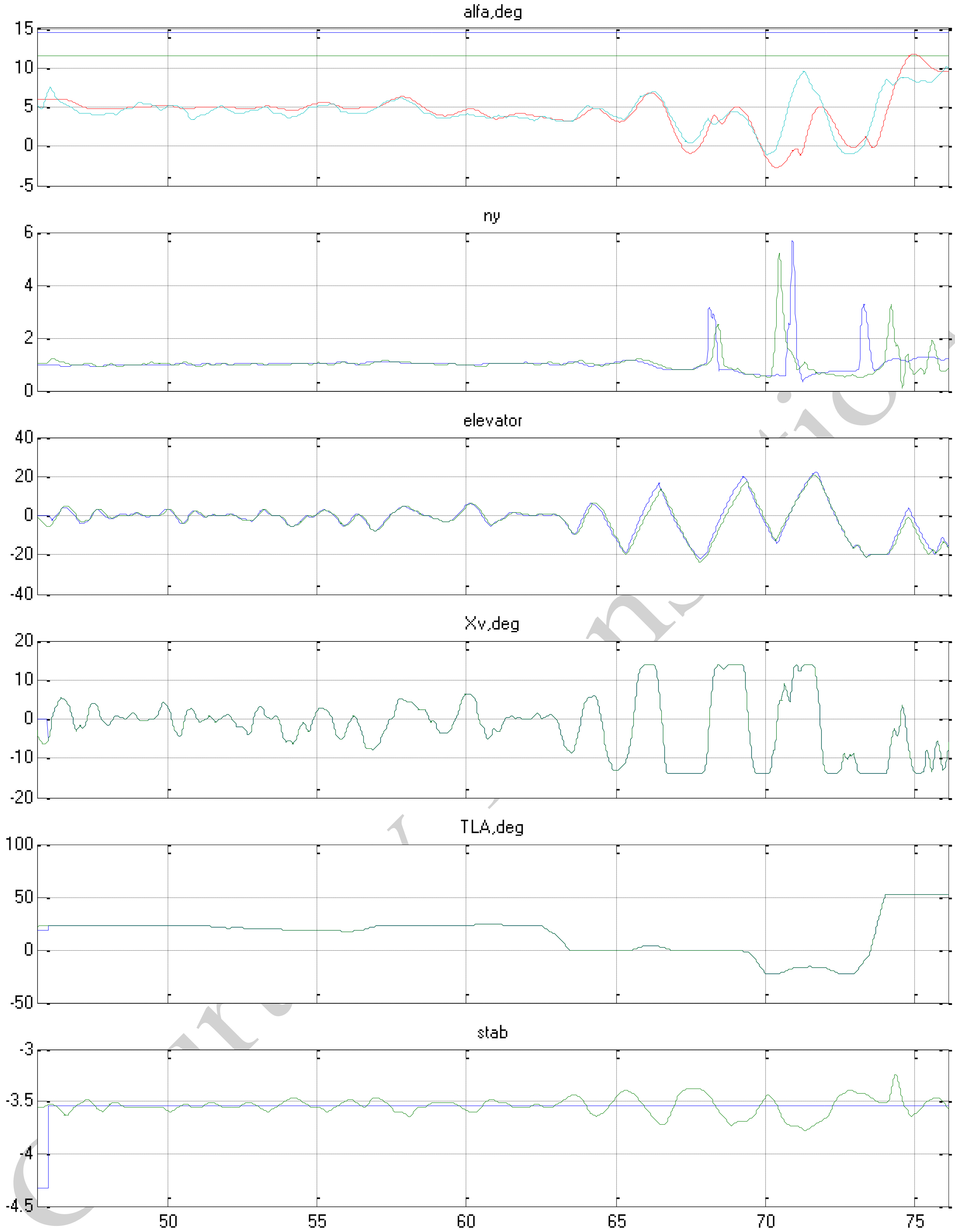

Fig. 99. The comparison of the flight data records and the results of the simulation. The control parameters

These figures show the estimated parameters in blue, the recorded ones are in green. As for the AOA plot, the red curve stands for the simulation, the turquoise one stands for the FDR record, the green curve represents α_{PROT}, the blue curve does α_{LIMIT}. As for the WOW plot: the blue curve stands for the NLG WOW sign as per the FDR record, the green curve does for the NLG WOW sign as per the model, the red curve is for the MLG leg WOW sign as per the FDR record, the turquoise one stands for the MLG leg WOW as per the model.

The given plots show the satisfactory convergence of the results of the simulation with the FDR record, including the region of the first bounce as well. The obtained degree of convergence allows concluding that this model can be used to study the effect of the flight conditions change against the landing leg.

1.16.22.6 The examination of the effect of the speedbrakes deployment after the first touchdown

The post-touchdown deployment of speedbrakes is an important factor in decreasing not only the landing distance, but the likelihood of another separation of the aircraft off the RWY as well due to the effect of the additional downforce (the decrease of the wing lift), generated at the speedbrakes deployment.

At the FBWCS DIRECT MODE not all the sections of speedbrakes are deployed, but only three outboard of them/multifunction spoilers. The deployment is done only manually (by the pilot). Two inboard sections/ground spoilers, integrating two conditions «retracted/deployed» only, are not operated in the FBWCS DIRECT MODE.

The simulation had been carried out in the conditions of the flight that ended up with the accident. At that up to the point of first touchdown (Ttouchdown = 68 sec.) the pilot's control inputs had been maintained in line with the FDR record. After touchdown, at the point of time of T = 69.5 sec., the control inputs as follows had been accomplished:

- The speedbrake handle setting to the spoilers full deployment position (speedbrake handle = FULL);
- the sidestick pressure release (sidestick = 0);
- the TL holding on the IDLE detent.

Fig. 100 - Fig. 102 present the results of the simulation. The color coding convention is the same as for the Figures above.

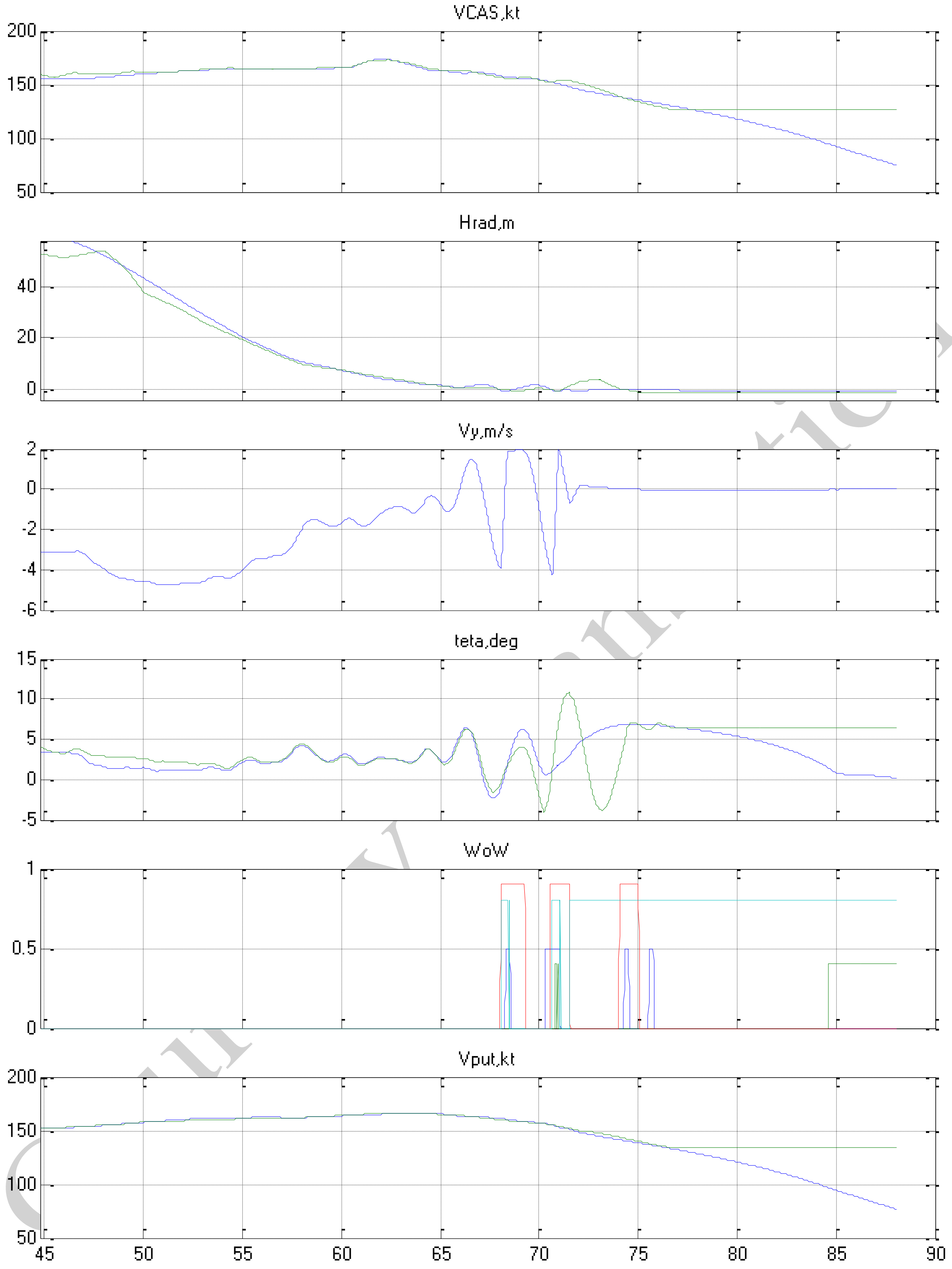

Fig. 100. The flight path parameters

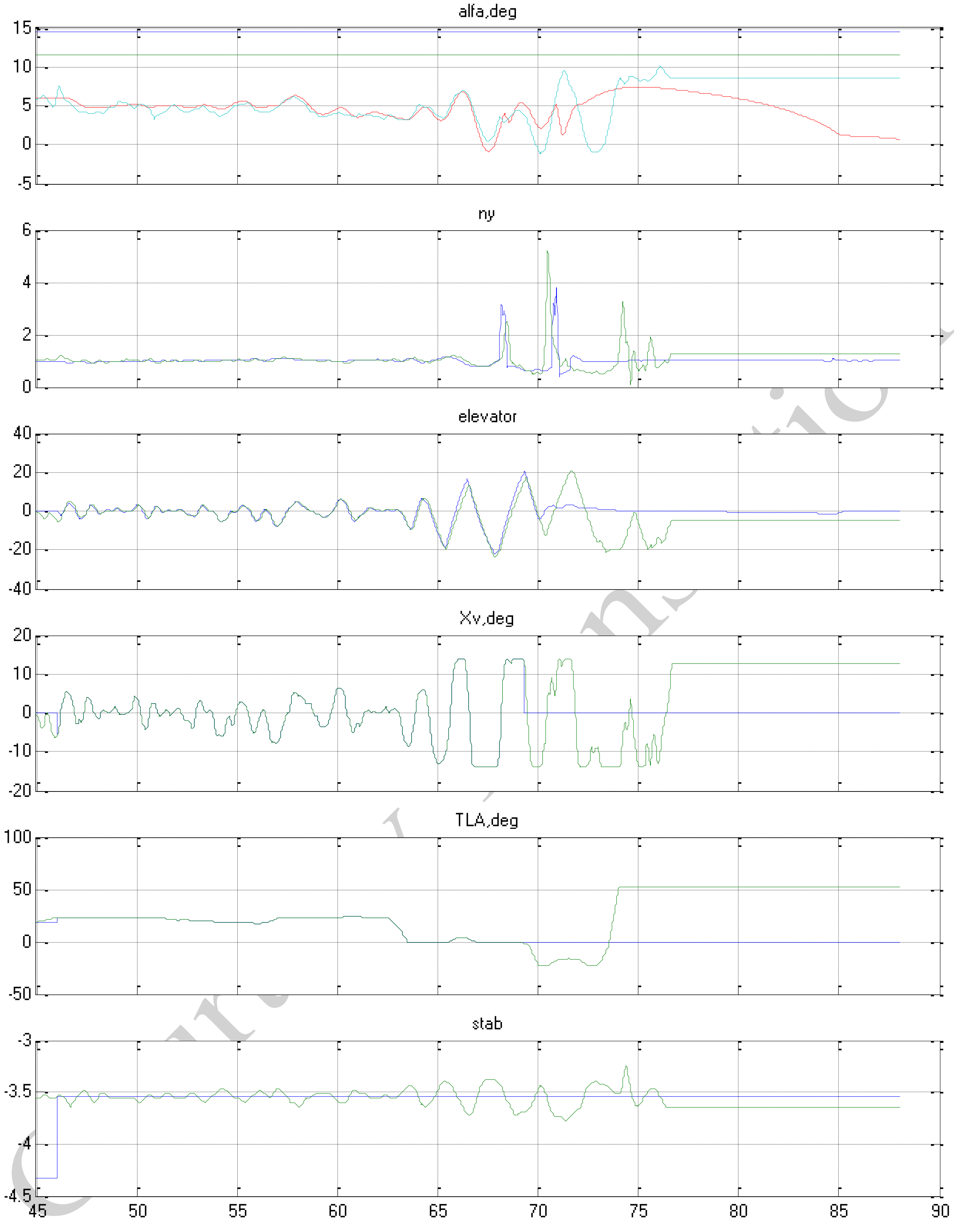

Fig. 101. The control parameters

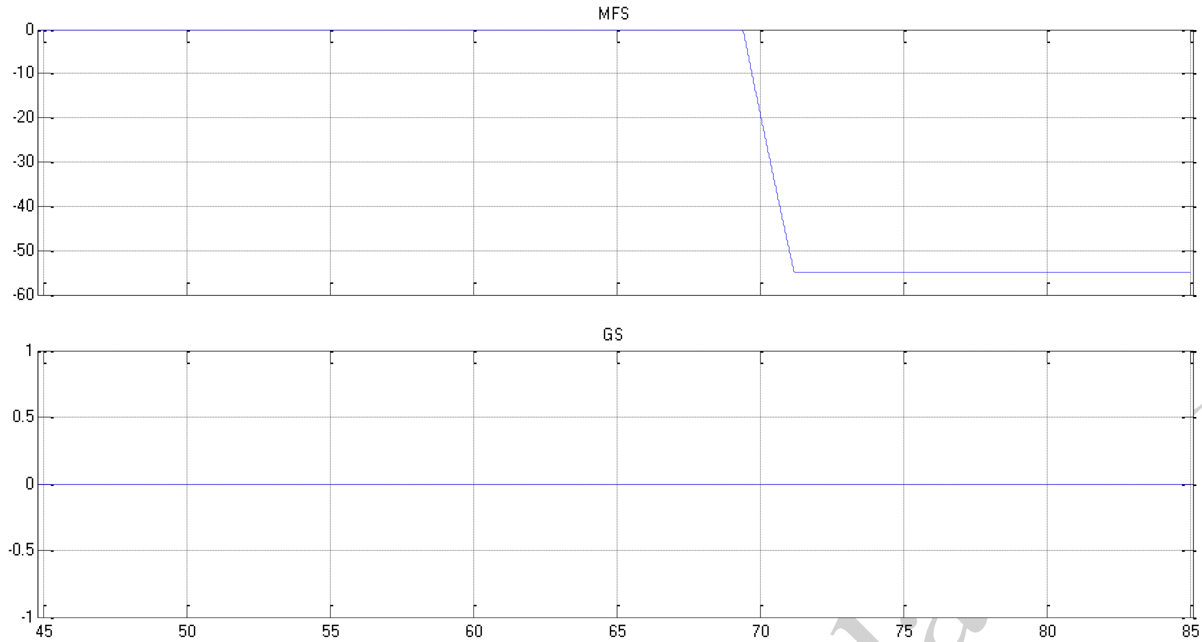

Fig. 102. The spoilers' operational mode

The analysis of the results is the evidence that the deployment of the spoilers after the first touchdown, while preserving the established way of piloting (prior to the point of the sidestick positioning to neutral at the simulation) does not lead to the elimination of another bounce of the aircraft off the RWY. However, because of the high nose-up moment out of the spoilers deployment, despite keeping the sidestick in the forward position into the first bounce, a significantly lower pitch rate to nose-down is evolved at the aircraft that allows preventing another touchdown with the NLG, coming first. Through this the maximum G that is generated at the second touchdown is significantly decreased (down to ≈ 3.8G instead of ≈ 5.85G) with no occurrence of another bounce.

1.16.22.7 The evaluation of the absence of the microburst effect before the flare

As stated above in the text of this Section, the condition for ensuring the convergence of ground speed and airspeed (as per the FDR record and the results of the simulation) is the presence of the wind microburst at the final leg of the landing.

The primary issue of this subsection is to evaluate the impact on the aircraft landing dynamics of the detected wind microburst. Fig. 103 shows the dependence of the wind velocity over time for the simulation of this task.

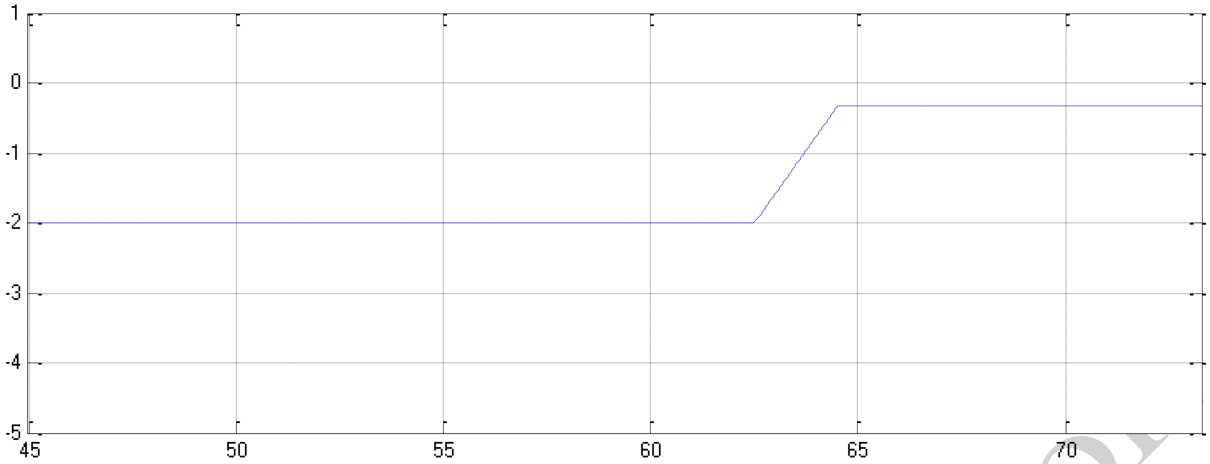

Fig. 103. The wind velocity at no burst, m/s

Fig. 104 and Fig. 105 present the results of the simulation. The color coding convention is the same as for the figures above.

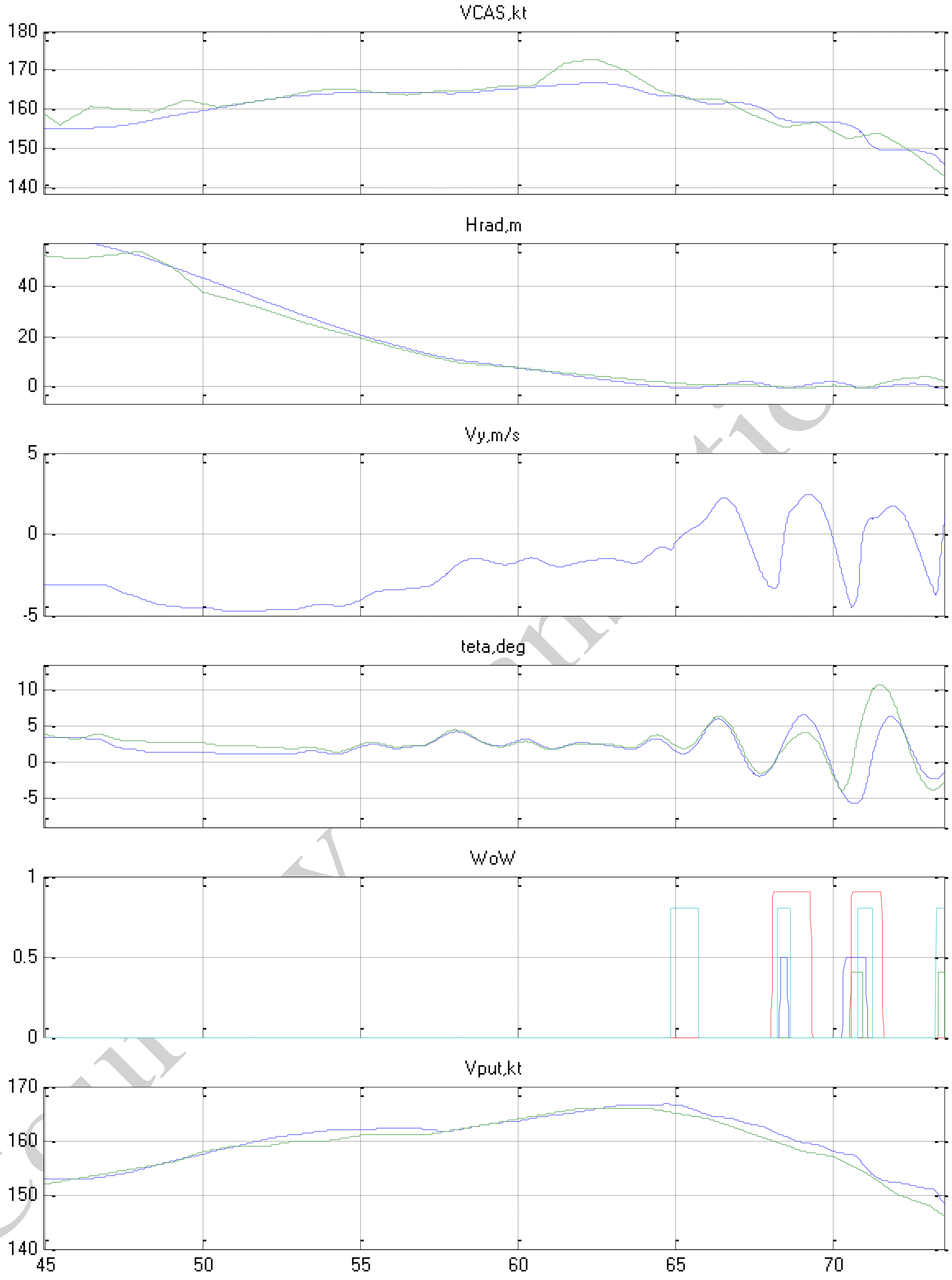

Fig. 104. Flight path parameters

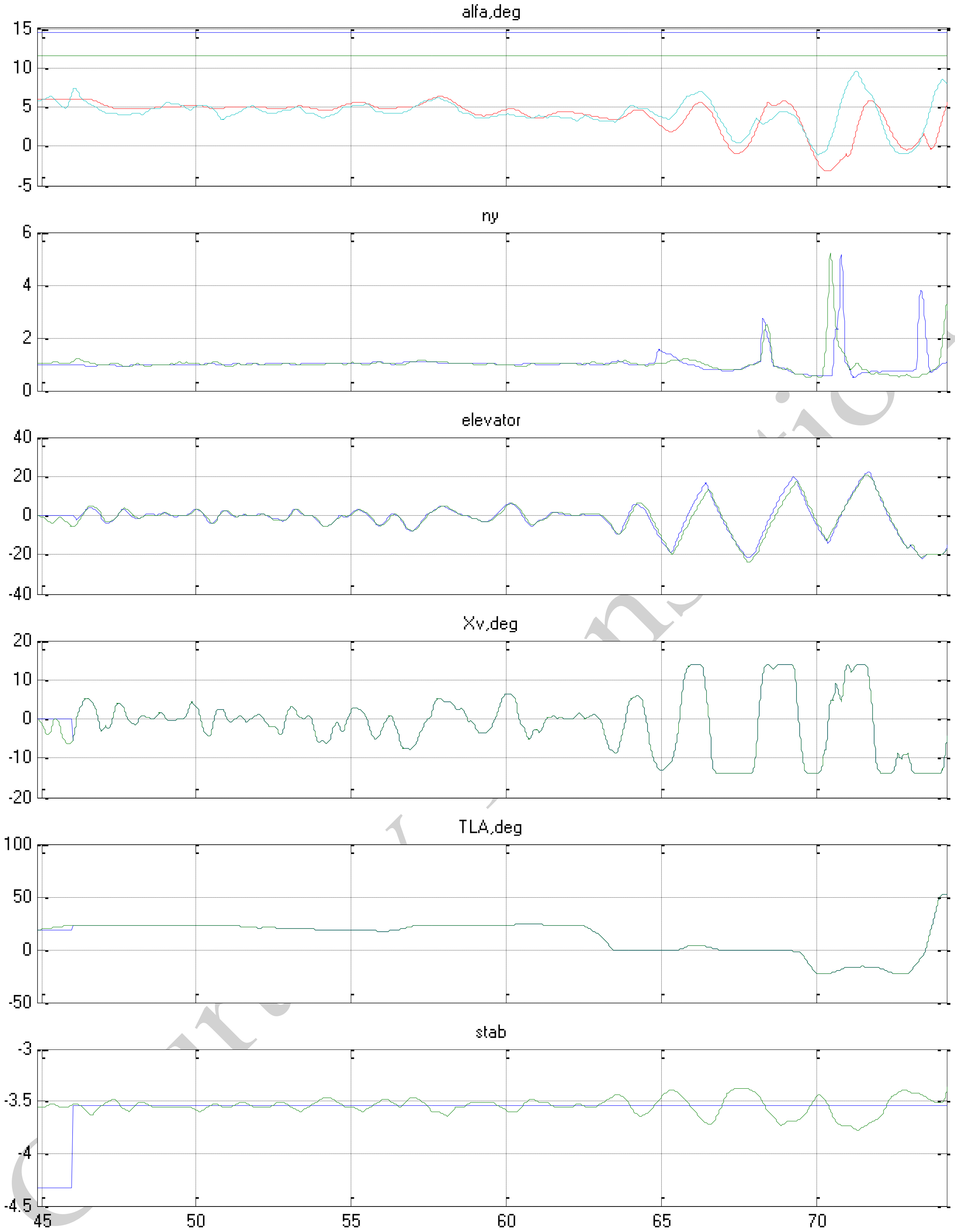

Fig. 105. Control parameters

The analysis of the results is the evidence that at no microburst results in the further touchdown with a slight positive pitch attitude at 3 sec. before the «first» touchdown, recorded by the FDR. The touchdown occurs at low vertical speed, while preserving the way of the sidestick control, is accompanied with the instant aircraft separation, at that the further dynamics of the airplane motion is no different from this, recorded by the FDR.

Meanwhile the very fact of the presence of touchdown and its feeling by the PF could have significantly altered the nature of the subsequent control inputs.

1.16.22.8 The effect of the FBWCS operational mode on the stage of landing

The simulation had been carried out in the conditions of the flight under consideration at the FBWCS in NORMAL MODE, where down to the altitude of 50 ft. the stab auto trim function is enabled. The auto trim function automatically deflects the stabilizer by the condition on minimizing of the averaged elevator deflection. To maintain the flight path convergence the dependence of the sidestick deflection is shifted upwards (to nose-down) by the angle of 0.3 deg. before initiation of flare (Trel = 63 sec.).

Fig. 106 and Fig. 107 present the results of the simulation (without the automatic deployment of ground spoilers at the landing roll) and Fig. 108 - Fig. 110 do with the automatic spoilers deployment at the landing roll. As for the indicated figures the parameters, obtained as the outcome of the simulation are shown in blue, the FDR record parameters are in green.

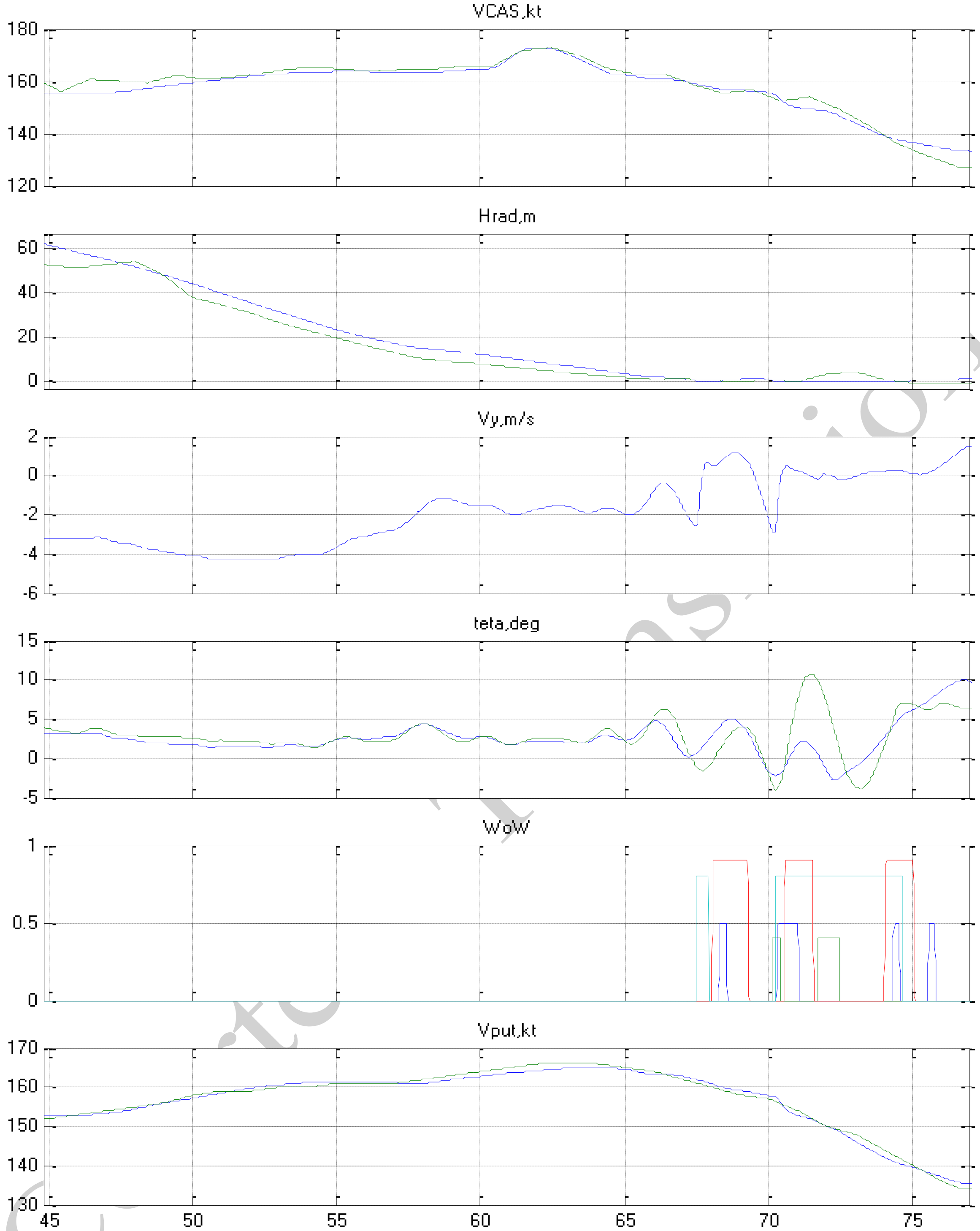

Fig. 106. The NORMAL MODE. SPDBRK = 0. The flight path parameters

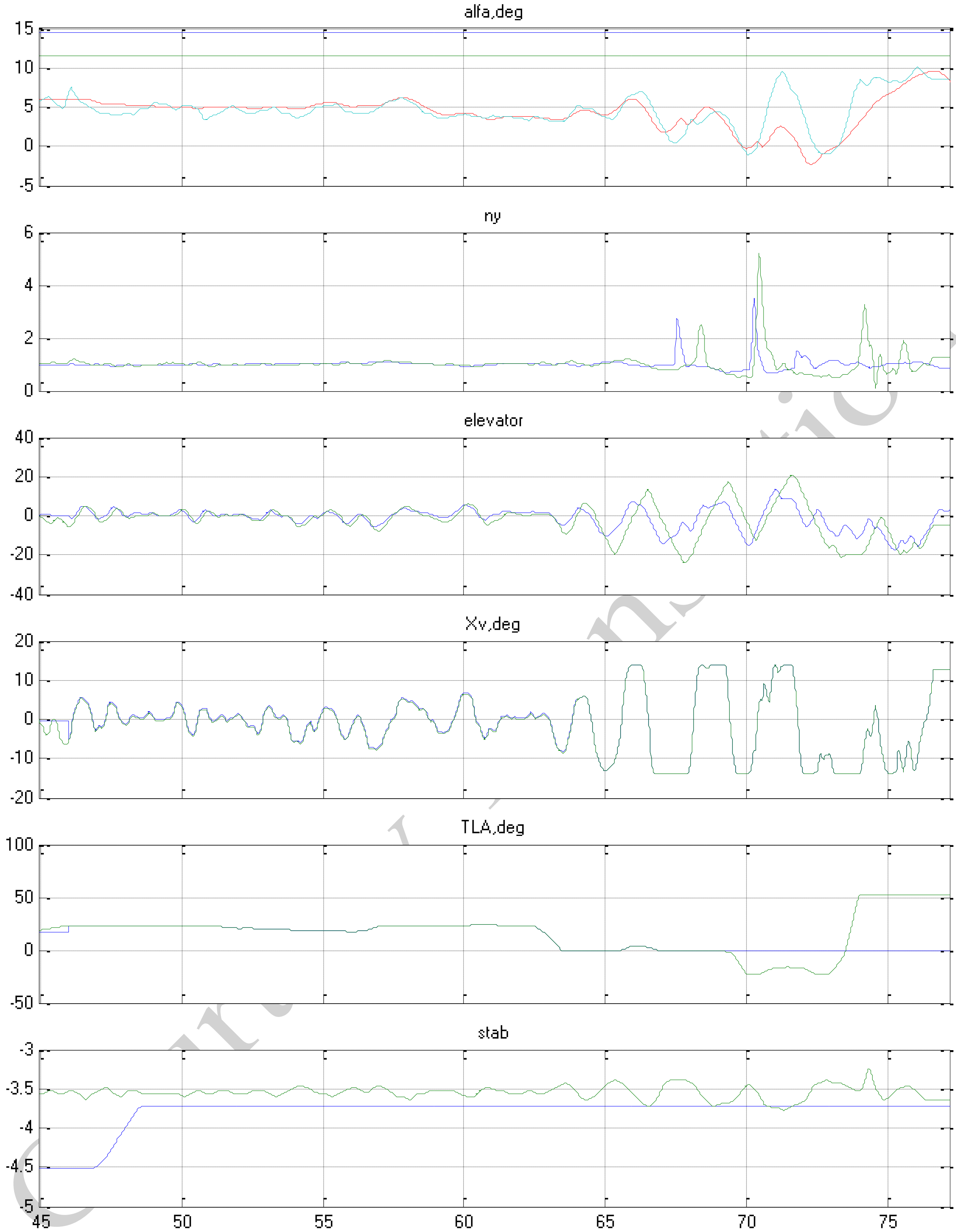

Fig. 107. The NORMAL MODE. SPDBRK = 0. The control parameters

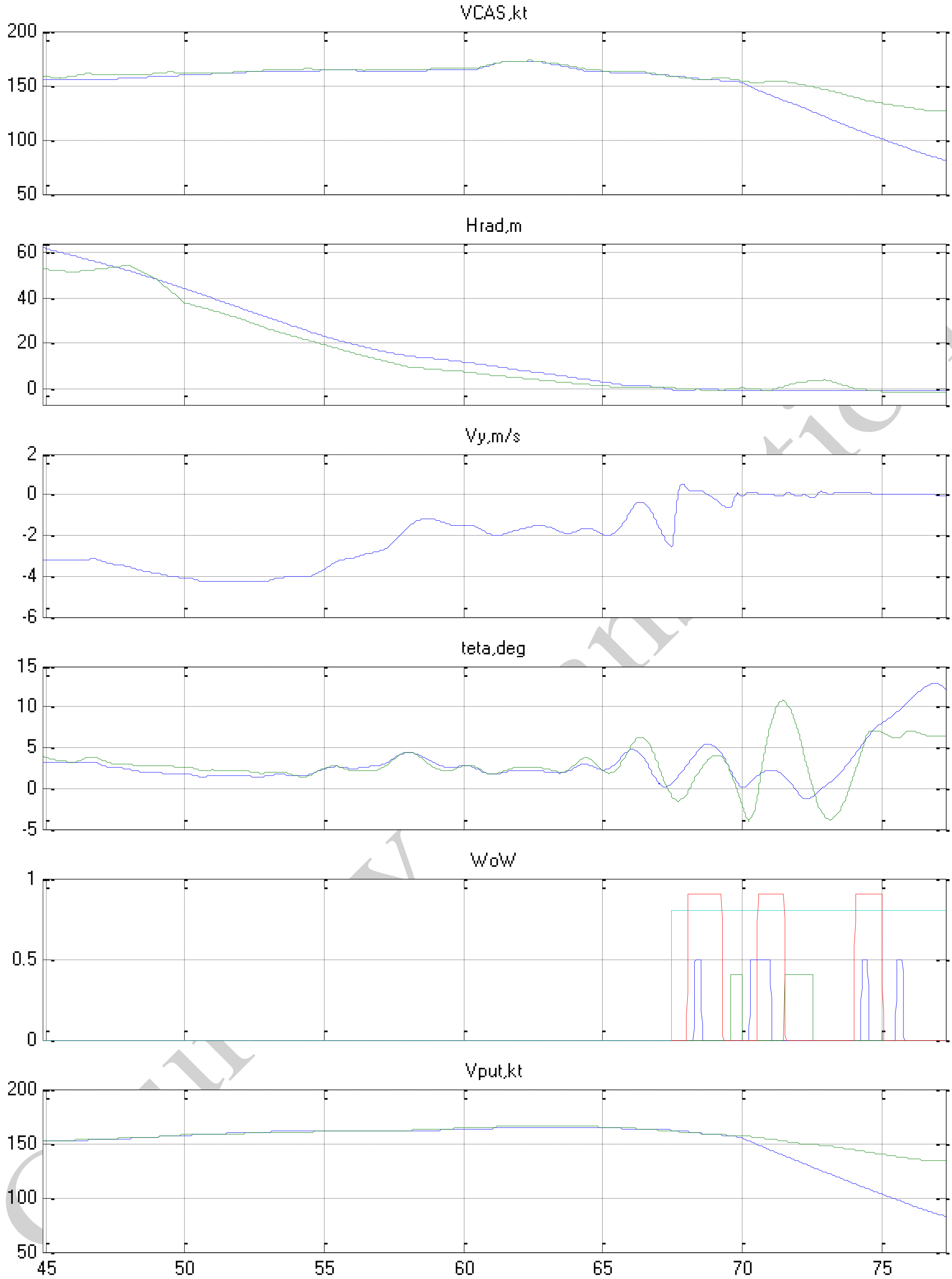

Fig. 108. The NORMAL MODE. SPDBRK = ARMED. The flight path parameters

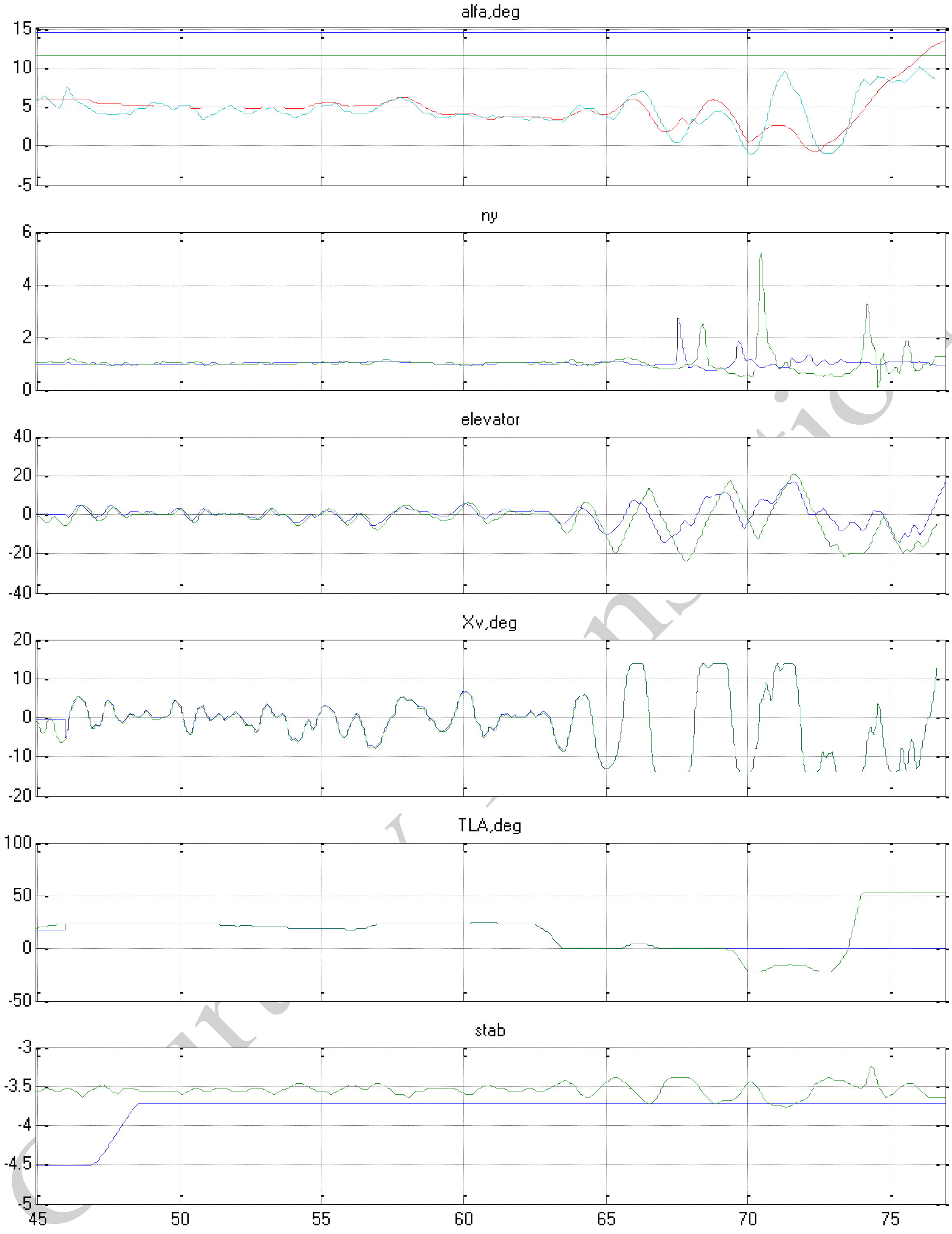

Fig. 109. The NORMAL MODE. SPDBRK = ARMED. The flight path parameters

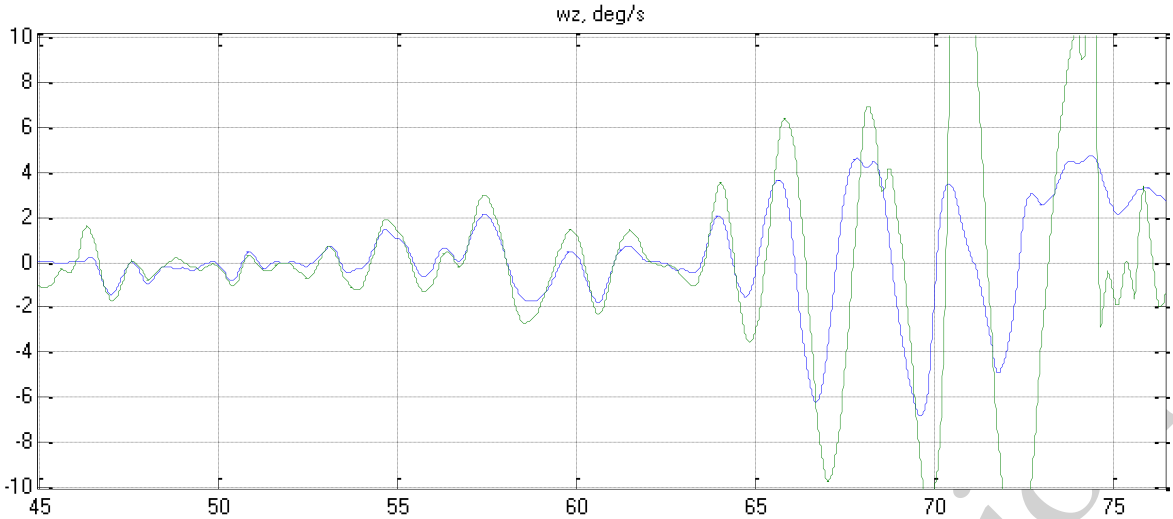

Fig. 110. The comparison of the pitch rates (deg/sec), SPDBRK = ARMED

The analysis of the simulation results is the evidence that without the automatic deployment of ground spoilers the post-touchdown aircraft bounces are preserved. At that the second touchdown occurs with the NLG coming first as well, with the less value of the pitch attitude, which decreases the maximum G at the second touchdown down to 3.6G and allows avoiding another aircraft bounce after the second touchdown due to the post-touchdown lower pitch rate to nose-up.

In the event of the automatic deployment of ground spoilers there is no occurrence of another aircraft separation off the RWY after the first touchdown. The maximum G at touchdown amounts to about 2.6G. At that the NLG lowering on the RWY occurs with the significant angular rate, which causes the second G spike (2.0 G).

At that as the control inputs by the pilot largely depend on the aircraft response, it is the aircraft response to the initial sidestick inputs by the PIC (at the initiation of flare) that had been the primary concern. The given plots are the evidence that at the FBWCS operation in DIRECT MODE the aircraft response to the sidestick input in pitch is more dynamic, both in the accomplished deflection of the elevator and the aircraft response (the pitch rate and the pitch attitude).

1.16.22.9 The examination on the effect of altering the sidestick control inputs on the process of the final landing leg

Through this section, as far as the conditions of the flight that ended up with the accident are concerned, the sidestick control alterations are regarded:

– the sidestick relief after its aft input at the altitude of 40 ft (the incomplete flare landing from the altitude of 40 ft);

– the sidestick keeping retained at high flare (the go-around maneuver);

– the limitation of the forward sidestick input after the initiation of flare.

The incomplete flare landing from the altitude of 40 ft

Between the altitudes of 40 ft – 16 ft the PF had dynamically reduced the aircraft descent rate by the aft sidestick input that resulted in the reduction of the flight path angle from -2.5^0 down to -1.3^0. It may be interpreted as the early flare with reaching the sink rate, close to the recommended one. In this case to perform the incomplete flare landing the pilot should have released the sidestick back pressure to interrupt the proceeding of flare with the complete arrest of the vertical speed.

The simulation had been carried out in the conditions of the flight that ended up with the accident, still at the sidestick kept held in neutral at the point of time T = 63 sec. (the altitude of 16 ft) instead of its aft input up to 8.8° that had been accomplished by the pilot into the flight that ended up with the accident.

Fig. 111 and Fig. 112 present the outcome of the simulation.

The analysis of the results is the evidence that the piloting technique of the kind at the landing eliminates another aircraft bounce off the RWY after touchdown. The maximum G would have amounted to ≈ 2.0 units.

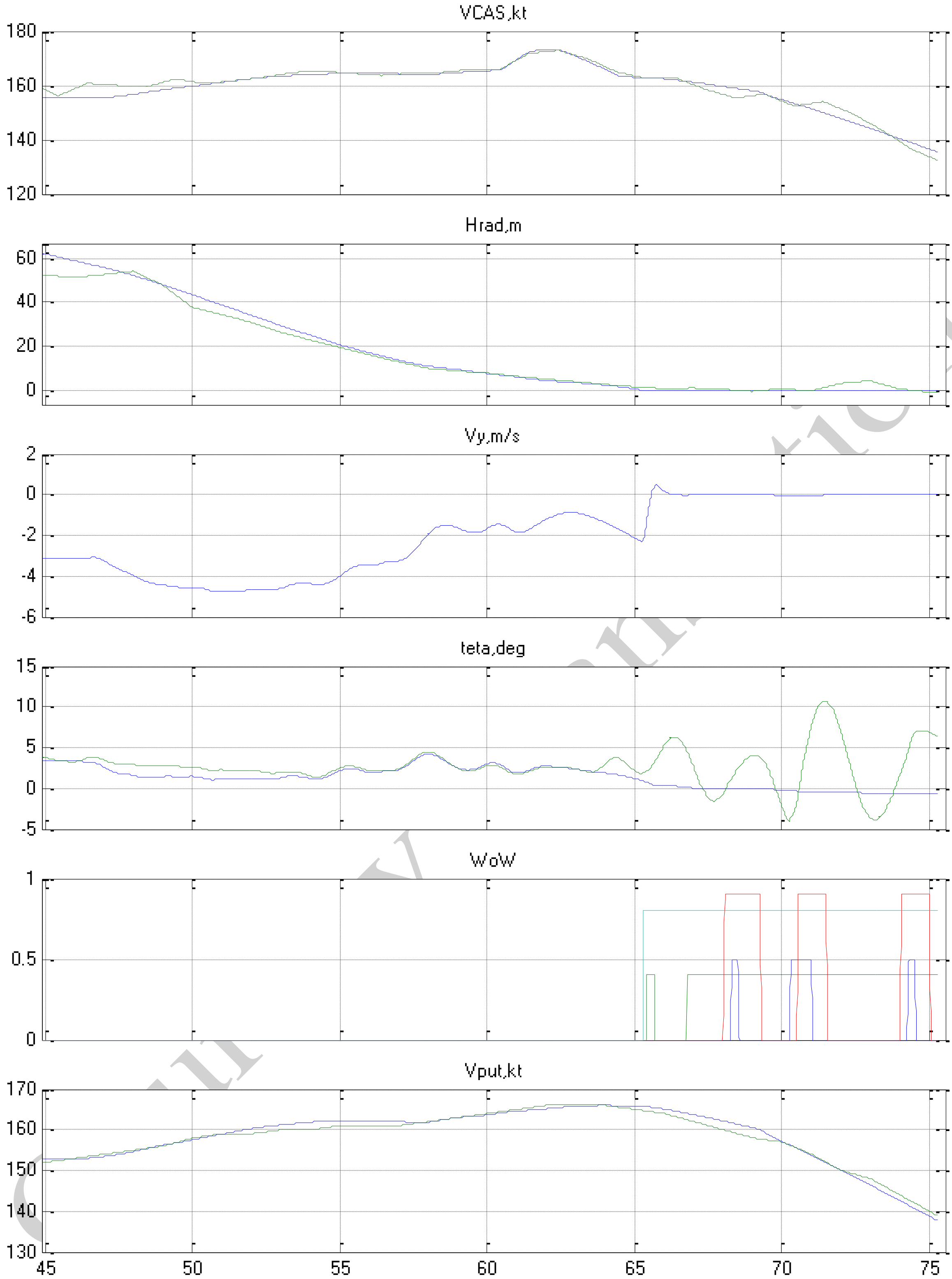

Fig. 111. Flight path parameters

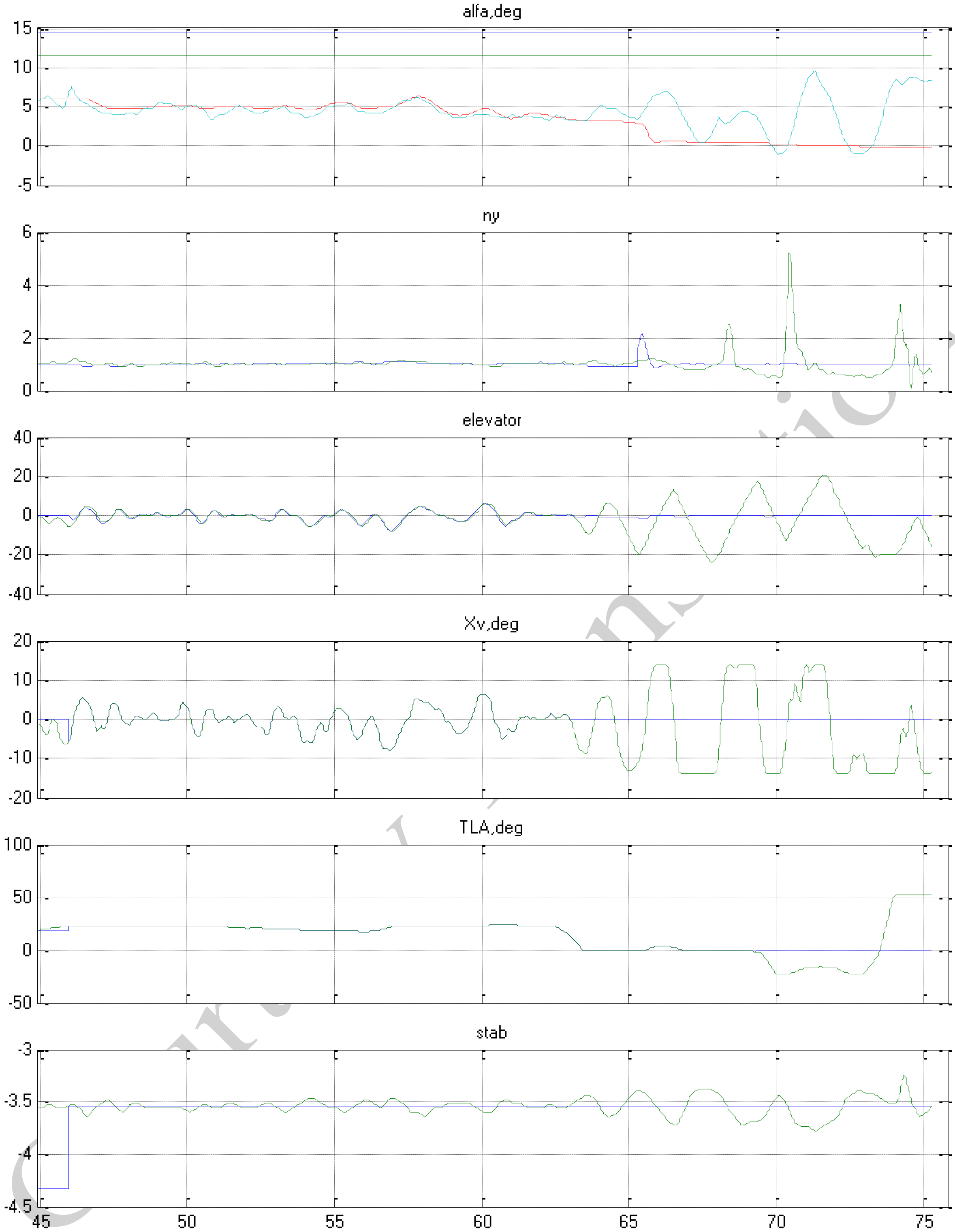

Fig. 112. Control parameters

The sidestick kept retained at high flare. The go-around maneuver

At the altitude of 16 ft. the TL retard to the IDLE detent was initiated. Nearly simultaneously with the TL retard to IDLE with aft sidestick input by 8.8^0 (65 % of travel) the pilot initiated the aircraft flare, which resulted in the onset of the positive pitch rate up to 3.5 deg/sec and the increase of G up to 1.15 units. This input was too «tough» and brought about the complete (early) aircraft flare above the RWY. At that point one of the way to complete the flight safely is to make the decision on go-around.

The simulation had been carried out in the conditions of the flight that ended up with the accident, still at the sidestick kept held in the reached position into the flare $Xv = 8.8^0$ to nose-up (T = 63.4 sec.).

Fig. 113 and Fig. 114 show the results of the simulation.

The analysis of the results indicates that as for this case the aircraft does not touch the RWY even on the condition of delayed increase of the engines power rating from IDLE to TOGA. At the altitude of 20 m the aircraft speed stays close to this, recommended by FCOM (155 kt), the aircraft is in positive climb with the rate of climb up to 8 m/sec.

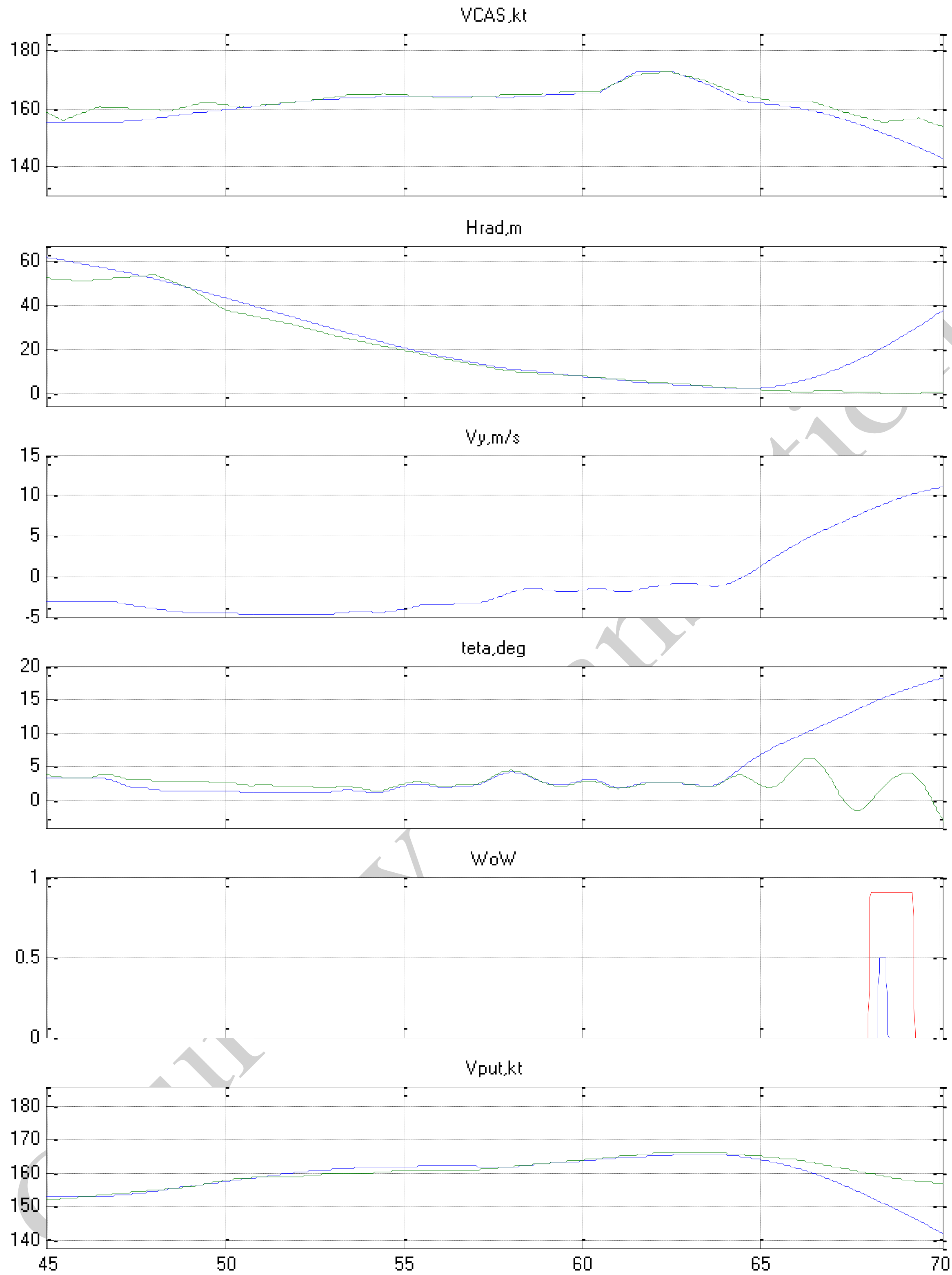

Fig. 113. The flight path parameters

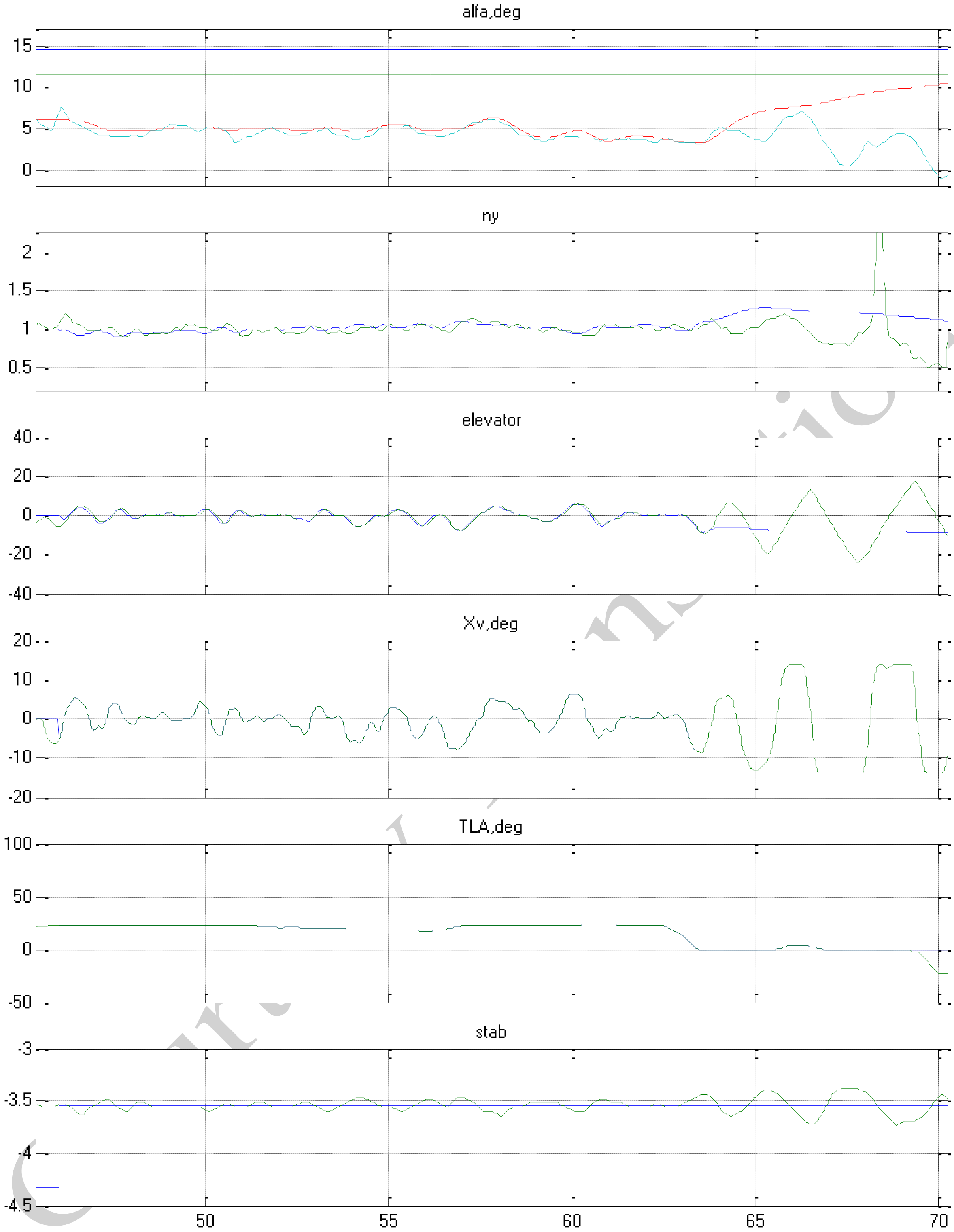

Fig. 114. The control parameters

The limitation of the forward sidestick input after the initiation of flare

Into the flight that ended up with the accident the aft sidestick input up to 8.8^0 (more than a half of travel) was instantly followed by its forward input beyond neutral up to 5.84^0 (43 % of travel) that resulted in the onset of negative pitch rate down to 3.6 deg/sec and decrease in G down to 0.95 unit.

The simulation had been carried out in the conditions of the flight that ended up with the accident, still at the sidestick kept retained neutral after the first input to flare.

Fig. 115 and Fig. 116 demonstrate the results of the simulation.

The review of the results indicates that the elimination of the forward sidestick input at preserving the preceding way of piloting prevents «the three points» touchdown and consecutive bounces after touchdown. The maximum G at touchdown would have amounted to ≈ 2.0 units.

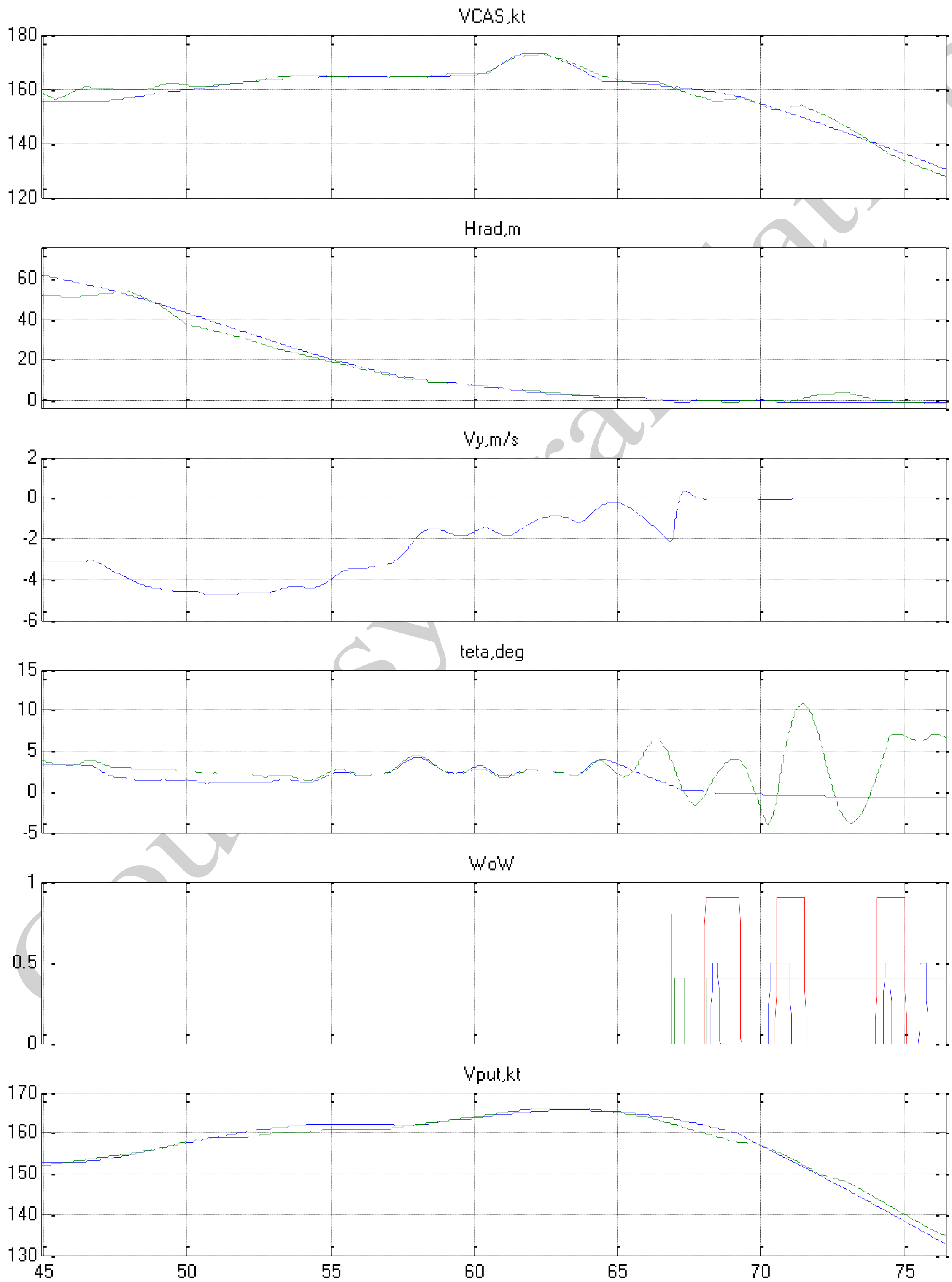

Fig. 115. Flight path parameters

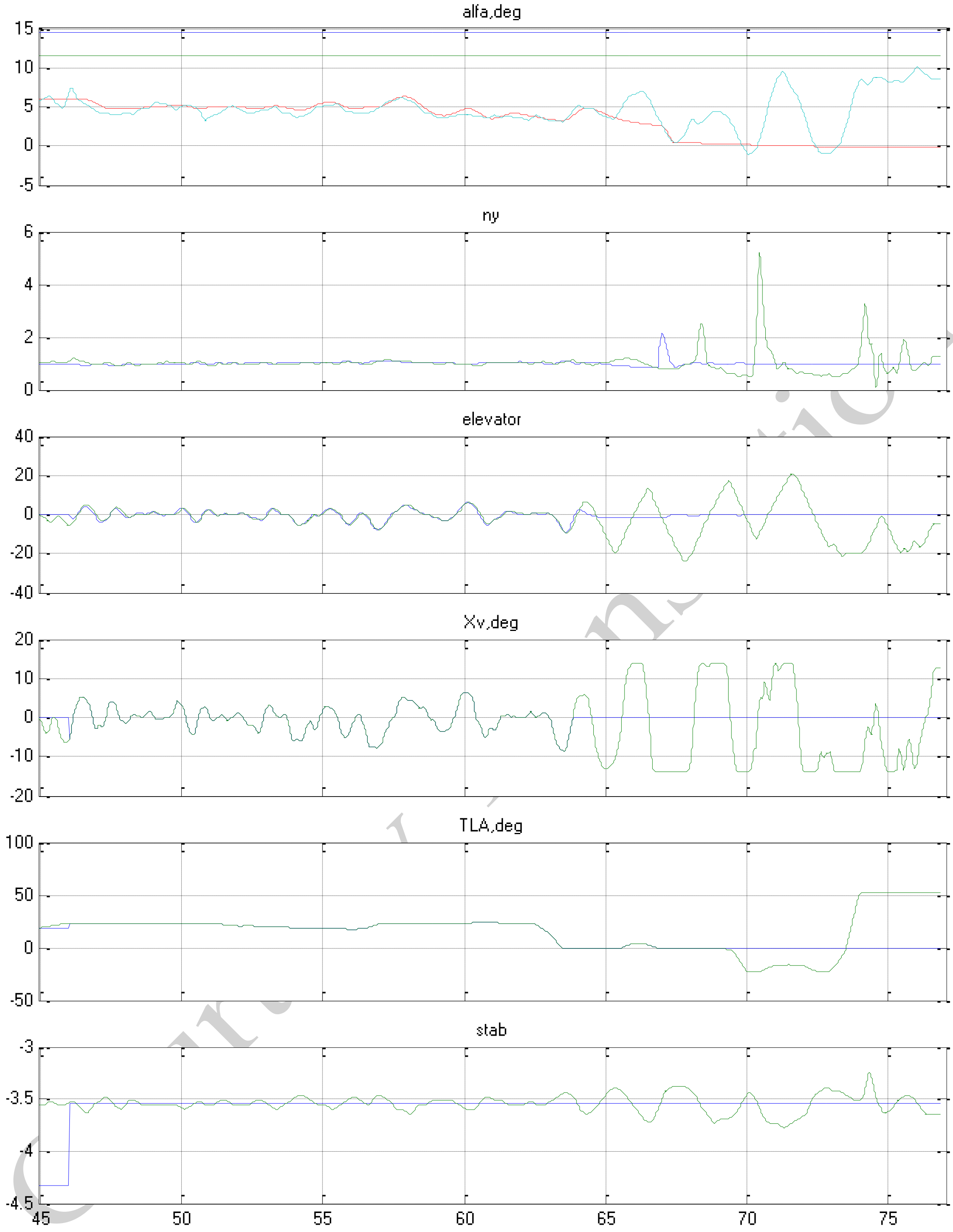

Fig. 116. Control parameters

1.16.22.10 The sidestick inputs[82] in pitch at different airspeeds

The description of the control laws in pitch channel is stated in Section 1.18.15 of the Report.

[82] The input term stands for the step deflection of the control handle and holding it.

To evaluate the effect of IAS on the sidestick input in pitch the simulation had been carried out as to three IAS values: 155 kt, 160 kt and 170 kt. The simulation is accomplished for the FBWCS DIRECT MODE (solid curve) and NORMAL MODE (dashed curve), FLAPS 3, landing gear down, true altitude less than 50 ft. The magnitude of the sidestick deflection had amounted to 9° that is it had been roughly consistent with the aft input magnitude at the initiation of flare into the flight that ended up with the accident. The outcome of the simulation is given on Fig. 117 - Fig. 119.

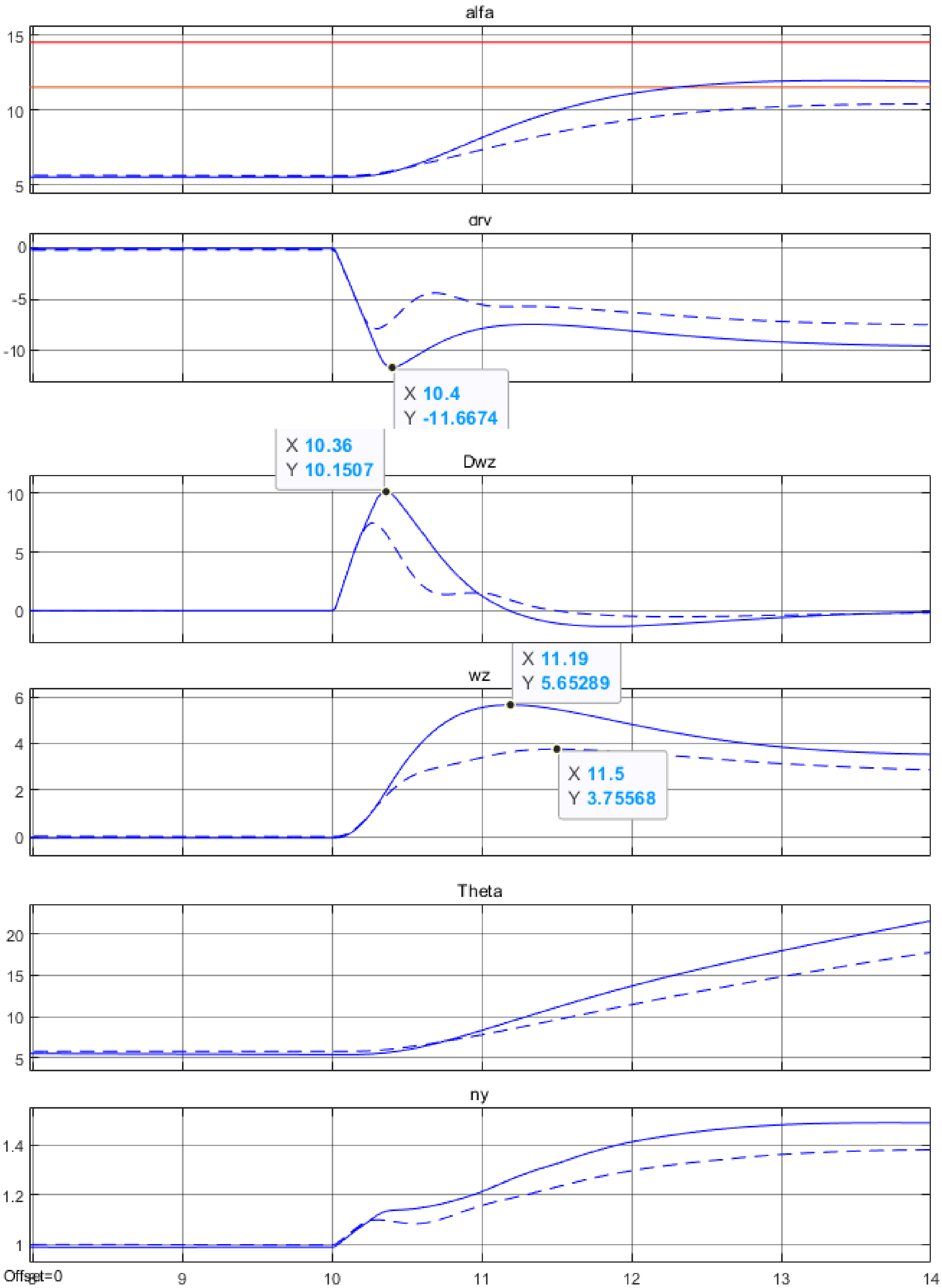

Fig. 117. The aft sidestick input, VCAS=155 kt

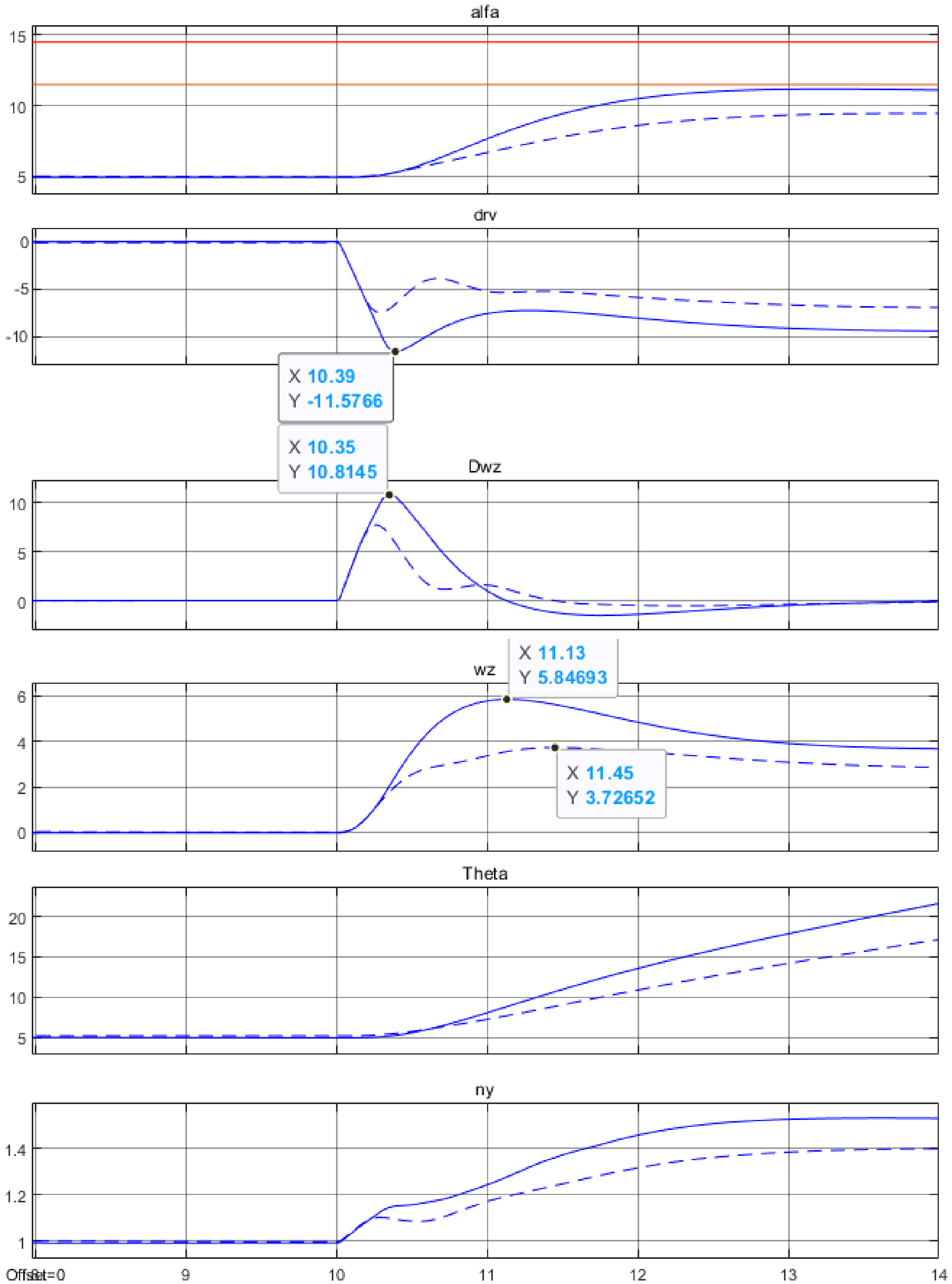

Fig. 118. The aft sidestick input, VCAS=160 kt

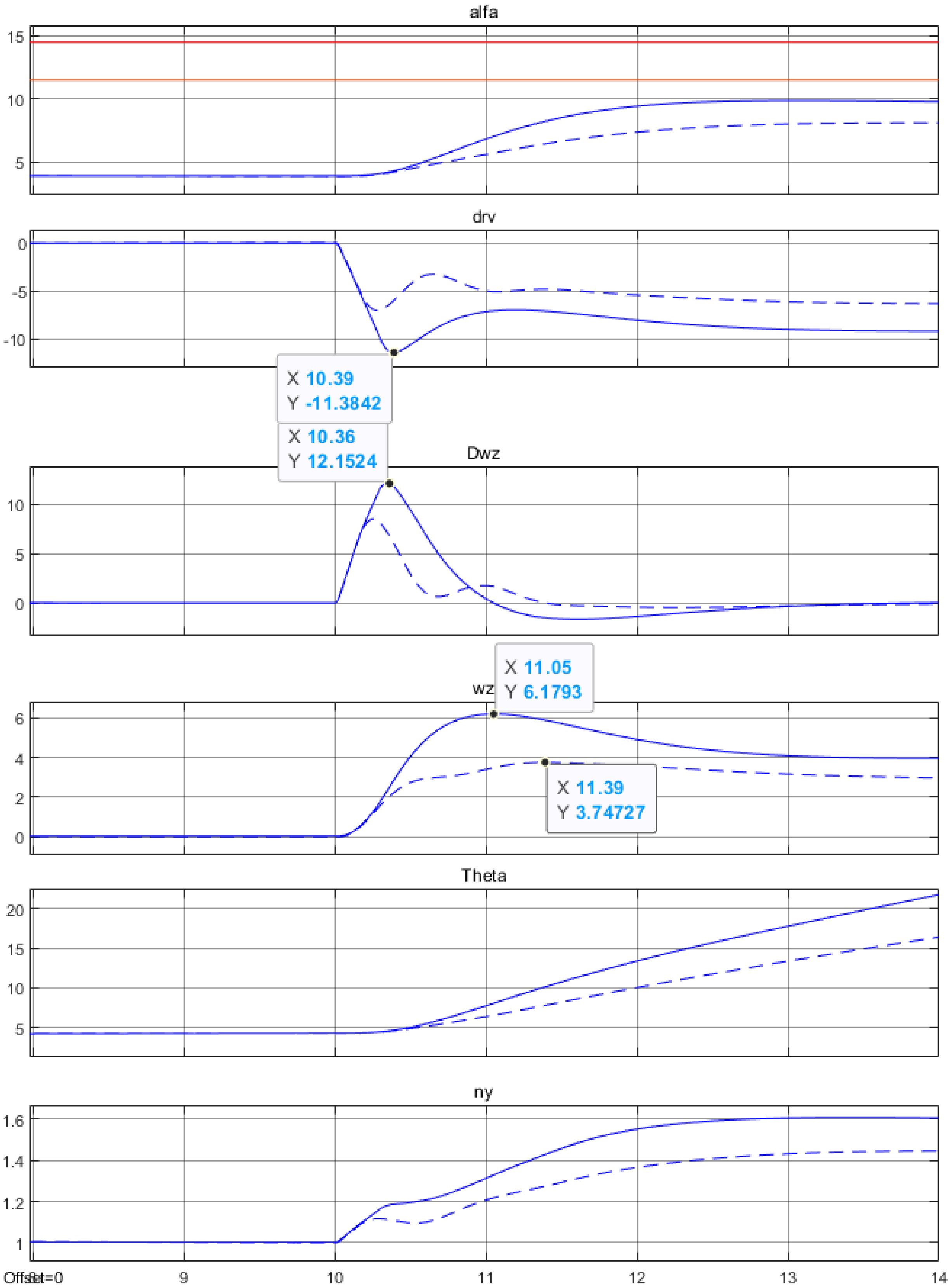

Fig. 119. The aft sidestick input, VCAS=170 kt

The results of the simulation are the evidence that in DIRECT MODE the aircraft response to the same sidestick input is the more dynamic the higher is IAS. As for NORMAL MODE the aircraft response is not affected by IAS.

At an early stage of the transient process the aircraft response to the sidestick inputs in both control modes is virtually the same. Further on the response in DIRECT MODE is more dynamic than in NORMAL MODE. The said difference is as well noted by test pilots at their evaluation of performance by denoting the aircraft response to the control input in pitch channel in DIRECT MODE as «*a bit more dynamic»* than in NORMAL MODE.

1.17 Organizational and management information

Aeroflot, PJSC was established pursuant to the Civil Code of the Russian Federation and the Federal Law on Joint Stock Companies. The full title is the Aeroflot Public Joint-Stock Company. The abbreviated title is Aeroflot, PJSC.

The location of the public joint-stock company is this of its executive authorities, of which the address is: 1, Arbat str., Moscow, Russian Federation 119019.

Aeroflot, PJSC has been issued the AOC # 1 of May 22, 1992, entitling to operate commercial air transport effective until its suspension or cancellation by the civil aviation executive authority.

Aeroflot holds the license # 14761-AT of July 29, 2020, issued permanent by Ministry of Industry and Trade of the Russian Federation to carry out the design, manufacture, testing and repair/overhaul of the aviation equipment.

Aeroflot, PJSC is a holder of the Maintenance Organization certificate # 285-16-148 of October 24, 2016, issued permanent (RRJ-95, A319/320/321, A319N/320N/321N/321NX, A330, A350-900, B737-800/900, and B777-300).

The RRJ-95 aircraft fleet (as of May 5, 2019) comprises 50 aircraft.

Sheremetyevo airport is the base one.

The air personnel (as of May 5, 2019) integrates:

– the RRJ-95 aircraft flight personnel:

– the pilots-in-command – 124 people; the first officers – 127 people; the flight attendants – 8479 people; the management and command employees – 5 people, flight test station – 9 people.

Engineering and technical staff (as of May 5, 2019) amounts to 2368 people.

The supervision (oversight) of the execution of the requirements by the aviation-related subjects to be supervised is exercised by the Federal Transport Oversight Service state aviation oversight territorial department, located at: 37-Building 1, Leningradsky avenue, Moscow, Russian Federation 125993.

1.18 Additional information

1.18.1 Summary table of the flights, having departed before and after the SU–1492 flight

Takeoff time	Flight number	Aircraft type	Ownership	SID	Request of avoidance	The ATC officer to have processed the request of avoidance
14:53	NWS377	B738	Russia	BST24E	There had been no request	
14:54	AFL1130	A320	Russia	BST24E	There had been no request	
14:55	AFL2164	SU95	Russia	AR24E	14:57 heading 270^{0}, 14:57:45 heading 290^{0}, 14:59 heading 270^{0}	Moscow Air Hub ATC center Sheremetyevo Radar sector radar control unit, frequency 118.1
14:57	AFL1364	SU95	Russia	BST24E	There had been no request	
14:59	CSA895	B739	the Czech Republic	AR24E	15:01 heading 290^{0}	Moscow Air Hub ATC center Sheremetyevo Radar sector radar control unit, frequency 118.1
15:00	AFL274	A333	Russia	BST24E	15:03:26 heading 290^{0}, 15:03:44 heading 300^{0}	Moscow Air Hub ATC center Sheremetyevo Radar sector radar control unit, frequency 118.1
15:03	AFL1492	SU95	Russia	KN24E	There had been no request	

Takeoff time	Flight number	Aircraft type	Ownership	SID	Request of avoidance	The ATC officer to have processed the request of avoidance
15:04	AFL1426	SU95	Russia	BST24E	15:08:17 the heading to the right to BESTA for the avoidance	Moscow Air Hub ATC center Sheremetyevo Radar sector radar control unit, frequency 118.1
15:06	AFL2138	B738	Russia	BST24E	There had been no request	
15:08	AFL2352	A321	Russia	AR24E	15:08:27 heading 220^0	
15:09	AFL2468	A320	Russia	AR24E	15:10:28 heading 220^0	
15:11	AFL2474	A320	Russia	AR24E	15:12:06 heading 230^0	
15:12	AFL261	A321	Russia	AR24E	15:13:43 heading 220^0	
15:14	AFL2382	A321	Russia	AR24E	15:14:45 heading 220^0	
15:17	KAR389	E190	Russia	BST24E	15:18:52 heading 330^0	
15:20	AFL1260	A320	Russia	BST24E	15:21:23 the heading to the right for avoidance	
15:24	AFL2002	A320	Russia	AR24E	15:25:18 heading 230^0	

1.18.2 Previous events of the RRJ-95 aircraft lightning encounter

#	MSN	Date	Circumstances	Consequences
1.	95024	20.11.2013	The lightning strike on the left part of the aircraft	No damage
2.	95028	27.05.2014	Lightning encounter	No damage

#	MSN	Date	Circumstances	Consequences
3.	95046	22.10.2015	Lightning encounter	No damage
4.	95046	03.12.2015	Lightning encounter	No damage
5.	95085	11.05.2016	Lightning encounter	No damage
6.	95029	04.06.2016	The lightning strike on the aircraft at the stand	No damage
7.	95054	08.07.2017	The lightning strike on the radome	No damage
8.	95048	12.07.2017	The lightning strike on the stabilizer	The replacement of the lightning-proof tape on the stabilizer
9.	95100	23.11.2017	The lightning strike on the right MLG door fasteners	Carbon deposit, the replacement of the fasteners
			The R6-F6H zone at the area of RAT	Carbon deposit, the replacement of the fasteners
			By the right fuselage	Carbon deposit, the paint coating restoration
			Adjacent to the stabilizer	Carbon deposit, the paint coating restoration
			On the upper fuselage	Carbon deposit, the paint coating restoration
10.	95100	29.11.2017	The lightning strike at the area of RAT at the R6-FGH zone	Carbon deposit, the replacement of fasteners
11.	95024	27.01.2018	The lightning strike	No damage
12.	95100	09.02.2018	The lightning strike on the aircraft fuselage	The replacement of the damaged fasteners

#	MSN	Date	Circumstances	Consequences
13.	95103	04.05.2018	The lightning strike adjacent to the rudder	The replacement of the static discharge cable, the rudder access door screw
14.	95025	23.05.2018	The lightning strike on the VDR 2 antenna and the wing skin	The replacement of the VHF2 antenna
15.	95118	27.05.2018	The lightning strike on the radome	The replacement of the radome
16.	95043	05.01.2019	The lightning strike on the VDR 2 antenna and the wing skin	The replacement of the VHF2 antenna

1.18.3 Previous known occurrences of the in-flight FBWCS reversion to DIRECT MODE

The known occurrences of the FBWCS reversion to DIRECT MODE before the date of the air accident are set out in the Table here below.

The date of the occurrence	Nationality and registration marks	The stage of the flight
24.03.2015	RA-89041	Cruise
10.04.2015	RA-89024	Approach
05.09.2015	RA-89046	Cruise
13.01.2016	RA-89011	Climb
03.08.2016	EI-FWA	Approach
14.03.2017	RA-89061	Approach
04.02.2018	RA-89014	Takeoff
05.02.2018	RA-89106	Takeoff

In the course of the investigation team activities the aircraft designer evaluated the estimated operational probability of the aircraft FBWCS reversion to DIRECT MODE. The period from the start of the production aircraft operation through the end of 2022. Over the given time interval there had been 21 occurrences of the subject reversion, including the events, set out in the Table above, against the total flight time of 1324891 hrs, enabling the estimated operational probability of 1.58E-05 per one flight hour.

The estimated design probability of the failure «The flagged failure of the FBWCS normal control mode with the automatic reversion to the minimum control mode» is 6.11E-07 per one flight hour.

With that the designer communicated that it had implemented technical arrangements to eliminate the causes of the FBWCS reversion to the minimum mode:

– the introduction of the СДУ6.0 software version over the aircraft fleet, thereby eliminating the causes of the reversion to the minimum control mode due to the failures of the airplane sidestick priority pushbutton. In 2015 there had been three occurrences of the reversion to the minimum mode. After the implementation of the СДУ6.0 software version in 2017 as per the RRJ-00-00075–БД bulletin there had been no occurrences recorded of the reversion to the minimum control mode because of the airplane sidestick priority pushbutton failures until the end of 2022;

– the software update to the СДУ6.5 version over the aircraft fleet according to the RRJ-27-00442–БД bulletin of July 22, 2022. This update would have prevented the reversion to the minimum control mode in 8 occurrences out of 21.

Hence the implementation of the proposed technical arrangements would have avoided 11 occurrences of the reversion to the minimum control mode. In this case the estimated probability would have been 7.45E-06 per one flight hour.

1.18.4 The QRH F/CTL DIRECT MODE Section

4	A-24	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	АЭРОФЛОТ RRJ-95 Оперативный сборник экипажа
	05.27	СИСТЕМА УПРАВЛЕНИЯ САМОЛЕТОМ	

F/CTL DIRECT MODE

Сопровождается речевым сообщением «DIRECT MODE» и автоматическим перемещением механизации крыла в положение FLAP ICE.

- МАКСИМАЛЬНАЯ СКОРОСТЬ..........................280 КТ / 0.8 М
  Скорость ограничена из за неработоспособности функции ограничения максимальной скорости в текущей конфигурации.
- A/T ....НЕ ИСПОЛЬЗОВАТЬ
- ПИЛОТИРОВАТЬ...ПЛАВНО
  Функция ограничения по углу атаки неработоспособна.
- БАЛАНСИРОВАТЬ...ВРУЧНУЮ
  Функция автоматического триммирования неработоспособна.
- SPEED BRAKE ....НЕ БОЛЕЕ 1/2
  Интерцепторы выпускайте и убирайте поэтапно для исключения чрезмерных изменений угла тангажа, с балансировкой в каждом положении.
- РАСХОД ТОПЛИВА ....УТОЧНИТЬ
  Уточните план полета, учитывая увеличение расхода топлива на 6% при полете на скорости более 0.72M в конфигурации FLAP ICE.

СТАТУС

- МАКСИМАЛЬНАЯ СКОРОСТЬ......................280 КТ / 0.8 М
- A/T........................НЕ ИСПОЛЬЗОВАТЬ
- ПИЛОТИРОВАТЬ.....................ПЛАВНО
- РАСХОД ТОПЛИВА............УТОЧНИТЬ
- SPEED BRAKE................НЕ БОЛЕЕ 1/2

ЗАХОД НА ПОСАДКУ И ПОСАДКА:

- ЗАХОД НА ПОСАДКУ...................ПСП
- ДЛЯ ПОСАДКИ ИСПОЛЬЗУЙТЕ FLAPS3
- TAWS LDG FLAP3..........................ON
- СКОРОСТЬ V_{APP}..................VREF+10 КТ
- ПОСАДОЧНАЯ ДИСТАНЦИЯ.............УВЕЛИЧИТЬ В 1.34

● **После приземления:**
  - SPEED BRAKE......УСТАНОВИТЬ FULL

УХОД НА ВТОРОЙ КРУГ:

- РУД...NTO
  Нажмите кнопку TO/GA и вручную установите РУД в положение NTO

ОТКАЗАВШИЕ СИСТЕМЫ

NORMAL MODE
AP
FD

ВСЕ © АО «ГСС» 21 ЯНВ 2016

4	A-24 05.27	EMERGENCY AND ABNORMAL PROCEDURES FLIGHT CONTROL SYSTEM	AEROFLOT Russian Airlines RRJ-95 Quick Reference Handbook

F/CTL DIRECT MODE

Accompanied by the «DIRECT MODE» synthetic voice and automatic conversion of flaps to the FLAP ICE configuration.

- MAX AIRSPEED……………………………………………………280 KT / 0.8M

The airspeed is limited due to the inoperative high-speed protection for current configuration.

- A/T…………………………………………………………………DO NOT USE
- MANEUVER WITH CARE

AOA protection inoperative.

- TRIM………………………………………………………………MANUALLY

Auto trim inoperative.

- SPEED BRAKE…………………………………………………NOT MORE THAN ½

Deploy and retract spoilers step by step to prevent excessive pitch alterations with the trim in each position.

- FUEL FLOW……………………………………………………MONITOR

Modify the flight plan considering the increase of fuel flow by 6 % at the flight with airspeed more than 0.72M in FLAPS ICE configuration.

– MAX AIRSPEED……280 KT / 0.8M – A/T……………………DO NOT USE – MANEUVER WITH CARE – FUEL FLOW…………MONITOR – SPEED BRK…..........NOT MORE THAN ½ **Approach and landing:** – APPROACH………….ILS RAW DATA – FOR LDG USE FLAPS 3 – TAWS LDG FLAP 3…ON – Vapp……………………Vref + 10 kt – LDG DISTANCE……..MULTIPLY BY 1.34 • **After touchdown** – SPEED BRK………….SET FULL **GO-AROUND:** – TL………………………SET NTO *Press TO/GA pushbutton and manually set TL to NTO.*	**STATUS** **INOPERATIVE SYSTEMS** NORMAL MODE AP FD

1.18.5 The OVERWEIGHT LANDING QRH Section

АЭРОФЛОТ RRJ-95 Оперативный сборник экипажа	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ ПРОЧИЕ АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	A-01 05.80	9

ПОСАДКА С ПРЕВЫШЕНИЕМ ПОСАДОЧНОЙ МАССЫ

Если требуют условия, посадка может быть выполнена с массой, соответствующей максимальной взлетной массе.

- ПОСАДОЧНАЯ ДИСТАНЦИЯ .... УТОЧНИТЬ
- L AIR И R AIR .... OFF

Для получения максимальной располагаемой тяги на случай ухода на второй круг отключить систему кондиционирования воздуха.

■ **Если посадка с превышением посадочной массы выполняется вследствие отказа, требующего выполнение посадки в конфигурации FLAPS 3 или менее:**

- ПОСАДОЧНАЯ КОНФИГУРАЦИЯ .... ОПРЕДЕЛИТЬ

При планировании посадки с превышением максимальной посадочной массы определить посадочную конфигурацию по графикам Определение посадочной массы (Глава 3 РЛЭ) с учетом внешних условий и фактического посадочного веса

● **При уходе на второй круг:**

- FLAPS .... ИСПОЛЬЗОВАТЬ FLAPS 1 ИЛИ FLAPS 2

■ **В других случаях:**

- LDG CONF .... FLAPS FULL

● **При уходе на второй круг:**

- FLAPS .... ИСПОЛЬЗОВАТЬ FLAPS 2

НА СКОРОСТИ GREEN DOT:

- FLAPS FLAP1

Выпуск механизации крыла выполняйте в полете без крена.

Примечание : *Установка рукоятки FLAPS в положение 1 на скорости выше скорости GREEN DOT не рекомендуется, во избежание риска отказа управления предкрылками с индикацией текстового сообщения F/CTL SLATS LOCKED/FAULT.*

НА КОНЕЧНОМ ЭТАПЕ ЗАХОДА:

- ВЫДЕРЖИВАТЬ СКОРОСТЬ .... VREF

Выдерживайте скорость с таким расчетом, чтобы при пролете торца ВПП скорость была уменьшена до VLS.

Примечание : *Максимальная вертикальная скорость снижения перед касанием не более 360 FPM.*

Продолжение на следующей странице

01 АПР 2014 © ЗАО «ГСС» ВСЕ

10	A-01 05.80	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ ПРОЧИЕ АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	АЭРОФЛОТ RRJ-95 Оперативный сборник экипажа

Продолжение

ПОСЛЕ ПРИЗЕМЛЕНИЯ НА ОСНОВНЫЕ ОПОРЫ:

- РЕВЕРС ТЯГИ .... MAX
- SPEED BRAKE .... ПРОВЕРИТЬ/FULL

ПОСЛЕ ОПУСКАНИЯ КОЛЕС ПЕРЕДНЕЙ ОПОРЫ:

- ТОРМОЗА .... ПРИМЕНИТЬ

Максимальное торможение рекомендуется применить после опускания колес передней опоры и в соответствии с длиной ВПП выбрать интенсивность торможения.

RRJ-95 Quick Reference Handbook	EMERGENCY AND ABNORMAL PROCEDURES EMERGENCY AND ABNORMAL PROCEDURES - MISCELLANEOUS	A-01 05.80	9

OVERWEIGHT LANDING

If required, the landing may be performed with the weight, equal to MTOW.

– LDG DISTANCE……………………………………………………MODIFY

– L AIR and R AIR……………………………………………………OFF

To obtain maximum available thrust in case of go-around turn off the air conditioning system.

■ **If the overweight landing is performed due to failure that requires landing in FLAPS 3 configuration or less:**

– LDG CONF……...……………………………………………………DETERMINE

When the overweight landing is anticipated, the landing configuration should be determined by the Landing Weight plots (FCOM Chapter 3) with the consideration of the external conditions and actual landing weight.

- **At go-around:**

– FLAPS……………. USE FLAPS 1 or FLAPS 2

■ **For other cases:**

– LDG CONF……...……………………………………………………FLAPS FULL

- **At go-around:**

– FLAPS……………. USE FLAPS 2

AT THE GREEN DOT SPEED

– FLAPS……………. FLAPS 1

Extend flaps/slats in a level flight.

Note: At the speed, more than the GREEN DOT, the setting of the FLAPS handle to the FLAPS 1 detent is not recommended to avoid risk of the slat control failure with the display of the F/CTL SLATS LOCKED/FAULT message.

IN THE FINAL STAGES OF APPROACH

– MAINTAIN SPEED……………. VREF

Maintain the speed so that it is decreased down to VLS at the runway threshold.

Note: The maximum sink rate prior to touchdown should not exceed 360 FPM.

AFTER MAIN LANDING GEAR TOUCHDOWN

- TR……………. MAX
- SPEED BRAKE…………….CHECK/FULL

AFTER LOWERING OF THE NOSE WHEELS

- BRAKES……………. APPLY

Maximum braking is recommended to be applied after the nose wheels are lowered, then choose the braking rate by the runway length.

1.18.6 The W/S AHEAD QRH Section

АЭРОФЛОТ RRJ-95 Оперативный сборник экипажа	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	A-34	27
	ПРОЧИЕ АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	05.80	

СИГНАЛИЗАЦИЯ «W/S AHEAD»

Надпись «W/S AHEAD» индицируется на дисплеях PFD и ND командира самолета и второго пилота. Цвет надписи зависит от интенсивности и местоположения сдвига ветра.

Примечание: *Если при срабатывании речевых сообщений «WINDSHEAR AHEAD»/«GO AROUND WINDSHEAR AHEAD» экипаж убедился в отсутствии угрозы сдвига ветра, действия не требуются при условии, что:*
- нет других признаков сдвига ветра и
- система RWS работоспособна.
Учитывайте возможность ложного срабатывания сигнализации «W/S AHEAD» в некоторых аэропортах при взлете и посадке из-за специфики рельефа и препятствий, но всегда выполняйте действия при срабатывании сигнализации "WINDSHEAR".

СИГНАЛИЗАЦИЯ «W/S AHEAD» (цвет красный)

■ **Взлет:**

Сопровождается речевым сообщением «WINDSHEAR AHEAD»

■ **Перед взлетом**

Задержите взлет или выберите для взлета ВПП с наиболее благоприятными метеоусловиями.

■ **Во время разбега:**

Прекратите взлет.

Примечание: *Сигнализация «W/S AHEAD» заблокирована на скорости более 100 kt и до высоты 50 ft.*

■ **После отрыва:**

– РУД .... NTO

Конфигурация механизации крыла может быть измененена до входа в условия сдвига ветра.

– АР(если включен) .... ОСТАВИТЬ ВКЛЮЧЕННЫМ

– FD .... ИСПОЛЬЗОВАТЬ

Если требуется, полностью отклоните ручку SS на себя.

Примечание: *Если FD неисправен, установите начальный угол тангажа 15°, а затем, если требуется, для предотвращения потери высоты, увеличьте угол тангажа.*

Продолжение на следующей странице

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Продолжение

■ **Заход на посадку и посадка**

Сопровождается речевым сообщением «GO AROUND WINDSHEAR AHEAD»

- УХОД НА ВТОРОЙ КРУГ..ВЫПОЛНИТЬ
- AP(если включен)............................ОСТАВИТЬ ВКЛЮЧЕННЫМ
- FD..ИСПОЛЬЗОВАТЬ

Если требуется, полностью отклоните ручку SS на себя.

Примечание: Если FD неисправен, установите начальный угол тангажа 15°, а затем, если требуется, для предотвращения потери высоты, увеличьте угол тангажа.

СИГНАЛИЗАЦИЯ «W/S AHEAD» (цвет желтый)

Сопровождается речевым сообщением «MONITOR RADAR DISPLAY».

Выполните указания, изложенные ниже:

■ **Перед взлетом**

Задержите взлет до улучшения метеоусловий.

Для оценки условий выполнения взлета:

- используйте наблюдение за метеообстановкой, донесения пилотов и предупреждения, получаемые от системы оповещения о сдвиге ветра на малых высотах
- проверьте информацию о метеобстановке

Выберите для взлета ВПП с наиболее благоприятными метеоусловиями с учетом местоположения сдвига ветра.

Используйте метеолокатор перед выполнением взлета, чтобы убедиться в отсутствии сдвига ветра по направлению взлета.

Используйте режим TO/GA.

Тщательно контролируйте приборную скорость и тренд изменения приборной скорости на разбеге для наиболее раннего определения признаков сдвига ветра.

Продолжение на следующей странице

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W/S AHEAD WARNING

The W/S AHEAD message is displayed at the captain and F/O's PFD and ND. The color of the message depends on the location and severity of the windshear.

Note: *If at the trigger of the WINDSHEAR AHEAD/GO-AROUND WINDSHEAR AHEAD synthetic voice the crew made sure there is no windshear threat, no actions are required on condition that:*

- *there are no other signs of the windshear and*
- *the RWS system is operational.*

Known cases of spurious predictive windshear alerts have been reported at some airports, during either takeoff or landing, due to the specific obstacle environment. However always rely on any reactive windshear (WINDSHEAR).

WINDSHEAR AHEAD WARNING (RED)

- **Takeoff:**

Associated with an aural synthetic voice «WINDSHEAR AHEAD».

- **Before takeoff**

Delay takeoff or choose the runway with more favorable weather conditions for takeoff.

- **At takeoff run**

Reject takeoff.

Note: *The WINDSHEAR AHEAD is inhibited above 100 kts until 50 ft.*

- **When airborne**

– TR……………. NTO

The slat/flap configuration can be changed provided the windshear is not entered.

– AP (if engaged)……………. ON

– FD…………………………… USE

If necessary, the flight crew may pull the sidestick fully back.

Note: *If FD is inoperative, move toward an initial pitch attitude of 15º. Then, if necessary, to prevent a loss in altitude, increase the pitch attiude.*

Continued on Next Page

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Continuation

- **Approach and landing:**

Associated with an aural synthetic voice «GO-AROUND WINDSHEAR AHEAD».

- GO-AROUND……………. PERFORM
- AP (if engaged)………… ON
- FD…………………………USE

If necessary, the flight crew may pull the sidestick fully back.

Note: *If FD is inoperative, move toward an initial pitch attitude of 15º. Then, if necessary, to prevent a loss in altitude, increase the pitch attiude.*

WINDSHEAR AHEAD WARNING (AMBER)

Associated with an aural synthetic voice «MONITOR RADAR DISPLAY».

Apply precautionary measures, as indicated below:

- **Before takeoff**

Delay takeoff until weather conditions improve.

Evaluate takeoff conditions:

- monitor weather conditions, use the pilots' in-flight weather reports or the data by LLWAS;
- checking the weather conditions information.

Select the most favorable runway (considering location of the likely windshear).

Use the weather radar before commencing takeoff to ensure that the flight path clears any potential problem areas.

Use the TO/GA mode.

Monitor closely airspeed and airspeed trend during the takeoff run for early sings of windshear.

Continued on Next Page

1.18.7 The stabilized approach criteria and the SOP at the ILS approach as per the airline OM

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(b) в полете аэродром назначения выбран в качестве запасного, при этом:
- аэродром имеет независимые рабочие ВПП;
- последняя фактическая и прогнозируемая метеорологическая информация свидетельствует о том, что в течение времени использования аэродрома нижняя граница облаков (вертикальная видимость) и видимость на ВПП, выбранной в качестве запасной, будут соответствовать требованиям подпункта (а) пункта 8.1.3.2(2), а направление и скорость ветра (включая порывы) с учетом состояния ВПП соответствует установленным эксплуатационным ограничениям.

(13) Заход на посадку считается стабилизированным (*См. Таблицу 8.3-1-2*), если:
- до высоты 1000 ft над уровнем аэродрома создана необходимая посадочная конфигурация ВС; или
- при выполнении захода на посадку с применением визуального маневрирования – маневра «Circle-to-Land» посадочная конфигурация ВС создана до высоты не ниже 500 ft над уровнем аэродрома;
- угол наклона траектории и вертикальная скорость снижения соответствуют схеме захода на посадку, а вертикальная скорость снижения не превышает 1000 ft/min. Если конечный этап захода на посадку требует выдерживать вертикальную скорость снижения более 1000 ft/min, это необходимо оговаривать при проведении предпосадочной подготовки;
- режим работы двигателей соответствует посадочной конфигурации ВС, а приборная скорость не превышает значения Vapp + 20 knots и не менее Vapp - 5 knots при достижении высоты 500 ft над уровнем аэродрома;
- отклонения ВС от расчетной траектории снижения в пределах допустимых значений для выбранной системы захода на посадку, установленных по типам ВС в части В РПП;
- для выдерживания траектории снижения требуются небольшие корректирующие движения органов управления ВС;
- до высоты 500 ft над уровнем аэродрома экипаж полностью проинструктирован и выполнены в полном объеме карты контрольных проверок.

Таблица 8.3-1-2

Условия стабилизированного захода на посадку

Приборные метеорологические условия - IMC	Визуальные метеорологические условия – VMC (*)	Визуальное маневрирование – «Circle-to-Land»
1000 ft AAL	**1000 ft AAL**	**MDH, но не ниже 500 ft**
Посадочная конфигурация	Посадочная конфигурация	Посадочная конфигурация
Vy ≤ 1000 ft/min	Vy ≤ 1000 ft/min	Vy ≤ 1000 ft/min
Δ траектории снижения-норма	**500 ft AAL**	**500 ft AAL**
Небольшие корректирующие движения органов управления	Δ траектории снижения-норма	Δ траектории снижения-норма
500 ft AAL	Небольшие корректирующие движения органов управления	Небольшие корректирующие движения органов управления
Режим работы двигателей соответствует посадочной конфигурации	Режим работы двигателей соответствует посадочной конфигурации	Режим работы двигателей соответствует посадочной конфигурации
Vapp ≤ Vapp + 20 knots	Vapp ≤ Vapp + 20 knots	Vapp ≤ Vapp + 20 knots
Vapp ≥ Vapp - 5 knots	Vapp ≥ Vapp - 5 knots	Vapp ≥ Vapp - 5 knots
Брифинг + КК	Брифинг + КК	Брифинг + КК

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(b) in-flight the destination aerodrome is chosen as the alternate, at that
- the aerodrome has two independent active runways;
- the last actual and forecast meteorological information indicates that within the time of the aerodrome use the cloud base (vertical visibility) and RVR to the runway, chosen as the alternate will meet the requirements of item 8.1.3.2 (2), and the direction and the velocity of the wind (with gusts) given the runway condition meet the established operational limitations.

(13) The approach is considered stabilized (see Table 8.3-1-2), if:
- till the altitude of 1000 ft. AAL the required landing configuration of the aircraft is established; or
- at the Circle-to-Land approach the landing configuration of the aircraft is established of at least 500 ft. AAL;
- the flight path angle and the rate of descent follow the approach pattern and the rate of descent does not exceed 1000 ft./min. If the final approach requires the rate of descent more than 1000 ft./min it should be discussed at the BEFORE LANDING briefing;
- the engine power rating is consistent with the landing configuration of the aircraft, the IAS does not exceed Vapp + 20 kts and is not less than Vapp – 5 kts at reaching the altitude of 500 ft AAL;
- the deviations of the aircraft off the estimated descent path are within acceptable limits for the chosen landing system, determined by the aircraft types in the OM Part B;
- to maintain the descent path the slight corrective flight control inputs are required;
- till the altitude of 500 ft. AAL the crew is completely briefed, the checklists are done in full.

Table 8.3-1-2

The stabilized approach criteria

Instrument meteorological conditions/IMC	Visual meteorological conditions – VMC (*)	Circle-to-Land visual maneuvering
1000 ft AAL	1000 ft. AAL	MDH, but not less than 500 ft
Landing configuration	Landing configuration	Landing configuration
Vy ≤ 1000 ft/min ∆ descent path-standard	Vy ≤ 1000 ft/min	Vy ≤ 1000 ft/min
	500 ft AAL	500 ft AAL
Slight corrective flight control inputs	∆ descent path-standard	∆ descent path-standard
	Slight corrective flight control inputs	Slight corrective flight control inputs
500 ft AAL		
Engine power rating consistent with landing configuration	Engine power rating consistent with landing configuration	Engine power rating consistent with landing configuration
Vapp ≤ Vapp +20 knots	Vapp ≤ Vapp +20 knots	Vapp ≤ Vapp +20 knots
Vapp ≥ Vapp - 5 knots	Vapp ≥ Vapp - 5 knots	Vapp ≥ Vapp - 5 knots
Briefing + checklist	Briefing + checklist	Briefing + checklist

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PF	PNF
FLAPS FULL..............................ORDER	FLAPS FULL...........SELECT / ANNOUNCE
SPEED............................CHECK / SET	CONF TEST.........ANNOUNCE / PERFORM
CONF TEST...............................CHECK Проконтролируйте появление сообщения LDG CONF NORMAL на EWD	
LANDING CHECKLIST...COMPLETE	
FLIGHT PARAMETERS...CHECK Доложите об отклонении от заданных параметров полета: - скорости – 1000 ft/min; – «SINK RATE»; - заданной скорости захода +10 (V_{APP}-5) kt. – «SPEED». Максимальное отклонение: - 0,5 точки по курсу или по глиссаде; – «LOC» или «GLIDE»; - тангаж – 2.5° nose вертикальной down; 7.5° nose up – «PITCH»; - крен> 7° – «BANK». **Примечание!** При полёте ниже ВПР, доклад PNF «GLIDE» и/или срабатывание речевой информации «GLIDE SLOPE» является информативным. Контролируйте угол атаки ~ 6°	
1000 ft AGL	
	«ONE THOUSAND STABILIZED»............. ....ANNOUNCE
CHECK or ***«GO AROUND / FLAPS»***......... ....ANNOUNCE	
Если ВС не стабилизировано на траектории захода в посадочной конфигурации: ***«NOT STABILIZED. GO AROUND»***....................ANNOUNCE GO-AROUND...PERFORM	
DH (MDA / MDH) +100 ft	
	«APPROACHING MINIMUM»...ANNOUNCE
До DH (MDA / MDH)	
«CONTINUE» or ***«GO AROUND / FLAPS»***... ....ANNOUNCE	
DH (MDA / MDH)	
	«MINIMUM».........................ANNOUNCE
AT 50 ft AGL	
	Проинформируйте о текущем значении v/s

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PF	PNF
FLAPS FULL…………….. ORDER	**FLAPS FULL……SELECT/ANNOUNCE**
SPEED……………. CHECK/SET	**CONF TEST……ANNOUNCE/PERFORM**
CONF TEST……….CHECK Monitor the LDG CONF NORMAL message on EWD	
LANDING CHECKLIST ……………………………………………………. COMPLETE	
FLIGHT PARAMETERS ……………………………………………………. CHECK Call out the deviation off the target flight parameters - speed – 1000 ft/min; - «SINK RATE» - target approach speed +10 (Vapp – 5) kt - «SPEED» Maximum deviation - 0.5 dot on localizer or glideslope; - «LOC» or «GLIDE» - pitch - 2.5° nose vertical down; 7.5° nose down- «PITCH» - bank > 7° - «BANK» **<u>Note!</u>** - At the flight below of DH the PNF callout «GLIDE» and/or the «GLIDE SLOPE» synthetic voice trigger is informative. Monitor AOA ~ 6°	
1000 FT AGL	
	ONE THOUSAND STABILIZED…ANNOUNCE

PF	PNF
CHECK or GO-AROUND/FLAPS…ANNOUNCE	
If the aircraft is not stabilized on the approach path in landing configuration **NOT STABILIZED GO AROUND…ANNOUNCE** **GO-AROUND………………………..PERFORM**	
DH (MDA/MDH) + 100 FT	
	APPROACHING MINIMUM…ANNOUNCE
BEFORE DH (MDA/MDH) REACHED	
CONTINUE or GO-AROUND/FLAPS…ANNOUNCE	
DH (MDA/MDH)	
	MINIMUM ……………….ANNOUNCE
AT 50 FT AGL	
	Call out the current V/S

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1.18.8 SOP at the ILS approach as per the FCOM

АЭРОФЛОТ RRJ-95 Руководство по летной эксплуатации	СТАНДАРТНЫЕ ЭКСПЛУАТАЦИОННЫЕ ПРОЦЕДУРЫ	1.04.72 СТР. 5	
	ЗАХОД НА ПОСАДКУ ПО ILS		А-28

– **ПАРАМЕТРЫ ПОЛЕТА .... КОНТР/ОБЪЯВИТЬ**

- *ПП объявляет любые изменения FMA*
- *НП объявляет:*
  - *«SPEED», если скорость полета меньше чем заданная на (-5 kt), или больше чем заданная на (+10 kt)*
  - *«PITCH», если угол тангажа меньше чем (-2,5°), или больше чем (+10°)*
  - *«BANK», если угол крена становится больше чем 7°*
  - *«SINK RATE», если вертикальная скорость снижения больше чем 1 000 ft/min*
  - *«LOCALIZER», если отклонение более 1/2 точки*
  - *«GLIDE SLOPE», если отклонение более 1/2 точки*

Выполните уход на второй круг:

■ **<u>На высоте менее1000 ft и до высоты 100 ft</u>**

При срабатывании любой сигнализации уровня Warning и Caution (кроме сигнализации об отказе двигателя) , TRIPLE CLICK

■ **<u>На высоте менее 100 ft:</u>**

Только при срабатывании сигнализации APPROACH LOST, AUTO FLT AP OFF, AP OFF

<u>НА ВЫСОТЕ ПРИНЯТИЯ РЕШЕНИЯ+100 FT:</u>

– **«APPROACHING DECISION HEIGHT» .... ОБЪЯВИТЬ ИЛИ КОНТР**

<u>НА ВЫСОТЕ НЕ НИЖЕ ВЫСОТЫ ПРИНЯТИЯ РЕШЕНИЯ:</u>

– **«DECISION HEIGHT» .... ОБЪЯВИТЬ ИЛИ КОНТР**

– **ОБЪЯВИТЬ.................................... «CONTINUE» ИЛИ «GO AROUND, FLAPS»**

Не допускайте «подныривание» под глиссаду, сохраняйте стабилизированный угол снижения до выравнивания.

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- **FLIGHT PARAMETERS……..CHECK/CALL OUT**
  - PF calls out any FMA change
  - PNF calls out
    - «SPEED», if the airspeed is less than the target for (-5 kt), or more than the target one for (+10 kt)
    - «PITCH», if the pitch is less for (-2.5°), or more for (+10°)
    - «BANK», if the bank is exceeding 7°
    - «SINK RATE», if the sink rate is more than 1000 ft/min
    - «LOCALIZER», if the deviation is more than 1/2 dot
    - «GLIDE SLOPE», if the deviation is more than 1/2 dot

Perform go-around:

■ **On the altitude less than 1000 ft and until 100 ft**

At the activation of any WARNING or CAUTION (except for the ENGINE FAILURE warning), TRIPLE CLICK

■ **On the altitude less than 100 ft**

At the activation of APPROACH LOST, AUTO FLT AP OFF, AP OFF caution only

ON THE DH + 100 FT

- **«APPROACHING DECISION HEIGHT»…….....................CALL OUT or CHECK**

ON THE ALTITUDE NOT LESS THAN DH

- **«DECISION HEIGHT»………...CALL OUT or CHECK**
- **CALL OUT………...................................«CONTINUE»** or **«GO AROUND FLAPS»**

Do not allow ducking under glideslope, maintain stabilized angle of descent till flare.

1.18.9 The emergency evacuation procedures as per the airline QRH and OM

4	A-37 / 05.80	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ ПРОЧИЕ АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	АЭРОФЛОТ Российские авиалинии RRJ-95 Оперативный сборник экипажа

АВАРИЙНАЯ ЭВАКУАЦИЯ

- САМОЛЕТ .... ОСТАНОВИТЬ
- PARK/ALTN BRAKE .... ВКЛ
- ATC .... ДОЛОЖИТЬ

  Информируйте ATC о характере неисправности и намерении дальнейших действий.
- КАБИННЫЙ ЭКИПАЖ .... ИНФОРМИРОВАТЬ

  Выполните короткое и точное сообщение, чтобы предупредить кабинный экипаж о том, что может требоваться аварийная эвакуация.
- ENG MASTER L И ENG MASTER R .... OFF
- КНОПКИ-ТАБЛО FIRE (L ENG, R ENG И APU) .... НАЖАТЬ
- AGENT 1(L ENG)/AGENT 2(R ENG)/AGENT APU .... КАК ТРЕБ

  Использование кнопок-табло AGENT требуется в случае, когда индицируется сообщение ENG L(R) FIRE или APU FIRE.

● **Если MODE (на пульте CAB PRESSURE) в положении MAN:**

- MAN RATE .... INCR

  Перед открытием дверей убедитесь в том, что значение ΔP = 0

■ **Если эвакуация требуется:**

- ЭВАКУАЦИЮ .... НАЧАТЬ

  Подайте короткую и точную команду о начале эвакуации. Подробнее смотрите QRH 05.90 ЭВАКУАЦИЯ ПАССАЖИРОВ И ЭКИПАЖА.
- BAT1, BAT2, BAT3, BAT4 .... OFF

■ **Если эвакуация не требуется:**

- КАБИННЫЙ ЭКИПАЖ И ПАССАЖИРОВ .... ИНФОРМИРОВАТЬ

  Информируйте кабинный экипаж и пассажиров, чтобы они оставались на своих местах.

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4	A-37	EMERGENCY AND ABNORMAL PROCEDURES	AEROFLOT Russian Airlines
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EMERGENCY EVACUATION

- AIRCRAFT……………………………………………………STOP
- PARK/ALTN BRAKE…………………………………………ON
- ATC………………………………………………………….NOTIFY

Report the nature of failure and the intended further actions to the ATC.

- CABIN CREW……………………………………………...ALERT

Make short and clear announcement to alert the cabin crew that the emergency evacuation may be required.

- ENG MASTER L and ENG MASTER R…………………………………………………OFF
- FIRE switchlights (L ENG, R ENG and APU)…………………………………………PRESS
- AGENT 1 (I ENG)/AGENT 2 (R ENG)/AGENT 3 (APU)………………………… AS REQRD

The application of the AGENT pushbuttons is required at the indication of the ENG L (R) FIRE or APU FIRE messages.

- **If MODE (on the CAB PRESSURE control panel) in the MAN position**
- MAN RATE…………………………………………………………………………...INCR

Before open the doors make sure that ∆p = 0.

■ **If evacuation is required**

- EVACUATION………………………………………………………………………INITIATE

Give a short and clear command on the evacuation initiation. See QRH 05.90 EVACUATION OF PASSENGERS AND CREW for details.

- BAT1, BAT2, BAT3, BAT4…………………………………………………………OFF

■ **If evacuation is not required**

- CABIN CREW AND PASSENGERS…………………………………………NOTIFY

Notify the cabin crew and passengers that they remain seated.

ALL JUNE 14, 2018

АЭРОФЛОТ	РУКОВОДСТВО ПО ПРОИЗВОДСТВУ ПОЛЕТОВ ЭКСПЛУАТАНТА. ЧАСТЬ В **Глава 4. Аварийные процедуры**	**РД-ГД-002** Изд. 2 / Рев. 04

4.6. ПРОЦЕДУРЫ АВАРИЙНОЙ ЭВАКУАЦИИ

Общие принципы процедуры «АВАРИЙНАЯ ЭВАКУАЦИЯ» изложены в 11 главе

EMERGENCY EVACUATION CHECKLIST
AIRCRAFT (CM1) .... STOP **PARK / ALTN BRAKE (CM1)..................................... ON** **ATC (CM2)..................................... NOTIFY** *"MAYDAY, MAYDAY, MAYDAY, AFL ___, EMERGENCY EVACUATION, EMERGENCY EVACUATION RWY ___"* **CABIN CREW (CM1)..................................... ALERT** **Если не был проинформирован**: *«ATTENTION CREW! ON STATION, ATTENTION CREW! ON STATION.»* **ENG MASTERS (L+R) (CM2 W/O CONFIRM) .... OFF** **ENG FIRE (L+R) и APU FIRE (CM2 W/O CONFIRM)..................................... PUSH** **ENG FIRE AGENTS (1L+2R) и APU (CM2 W/O CONFIRM) .... AS RQRD** *Использование кнопок-табло AGENT требуется в случае, когда индицируется сообщение ENG L (R) FIRE или APU FIRE*
Если MODE в положении MAN:
MAN RATE (CM2 W/O CONFIRM)..................................... FULL INCR POSITION Перед открытием дверей убедитесь в том, что значение ΔP = 0
Если требуется эвакуация:
EVACUATION (CM1) .... INITIATE *«PASSANGER EVACUATION. PASSANGER EVACUATION»* **BAT 1, 3, 2, 4 (CM2 W/O CONFIRM) .... OFF**
Если эвакуация не требуется:
CABIN CREW (CM1)..................................... NOTIFY *«CANCEL ALERT, CANCEL ALERT»* **ATC (CM2)..................................... NOTIFY** *«AFL ___, CANCEL DISTRESS, CANCEL DISTRESS»*

AEROFLOT Russian Airlines	THE OPERATOR'S OPERATIONS MANUAL. PART B **Chapter 4. Emergency procedures**	**РД-ГД-002**	
		Ed. 2	**Rev. 04**

4.6 EMERGENCY EVACUATION PROCEDURES

General principles of the EMERGENCY EVACUATION procedure are stated in Chapter 11.

EMERGENCY EVACUATION CHECKLIST

AIRCRAFT (CM1)……………………………………………………………………STOP
PARK/ALTN BRAKE (CM1)……………………………………………………………ON
ATC (CM2)……………………………………………………………………………NOTIFY
«MAYDAY MAYDAY MAYDAY, AFL____, EMERGENCY EVACUATION, EMERGENCY EVACUATION RWY_____»
CABIN CREW (CM1)…………………………………………………………………..ALERT
If not yet alerted: *«ATTENTION CREW! ON STATION, ATTENTION CREW! ON STATION»*
ENG MASTERS (L+R) (CM2 W/O CONFIRM) ……………………………………OFF
ENG FIRE (L+R) and APU FIRE (CM2 W/O CONFIRM) ………………………..PRESS
ENG FIRE AGENTS (1L+2R) and APU (CM2 W/O CONFIRM) ……………… AS RQRD
The application of the AGENT pushbuttons is required at the indication of the ENG L (R) FIRE or APU FIRE messages.

If MODE in MAN position

MAN RATE (CM2 W/O CONFIRM) ……………………………………FULL INCR POSITION
Before open the doors make sure that $\Delta p = 0$.

If evacuation is required

EVACUATION (CM1)…………………………………………………………………INITIATE
«PASSENGER EVACUATION. PASSENGER EVACUATION»
BAT 1, 3, 2, 4 (CM2 W/O CONFIRM) ……………………………………………OFF

If evacuation is not required

CABIN CREW (CM1)…………………………………………………………………..NOTIFY
«CANCEL ALERT. CANCEL ALERT»
ATC (CM2)……………………………………………………………………………NOTIFY
«AFL____CANCEL DISTESS. CANCEL DISTRESS»

1.18.10 The RRJ-95 QRH. The evacuation of the passengers and crew

12	A-17	АВАРИЙНЫЕ И ОСОБЫЕ ПРОЦЕДУРЫ	АЭРОФЛОТ RRJ-95 Оперативный сборник экипажа
	05.90	ЭВАКУАЦИЯ ПАССАЖИРОВ И ЭКИПАЖА	

ЭВАКУАЦИЯ НА СУШЕ

ПРОЦЕДУРЫ ДЛЯ ЛЕТНОГО ЭКИПАЖА

- **По команде «ВНИМАНИЕ! ПОСАДКА»**
  - РУЧКУ СТОПОРЕНИЯ РЕМНЕЙ В ПОЛОЖЕНИЕ РУЧНОГО СТОПОРЕНИЯ..УСТАНОВИТЬ

    Примечание : Кресло дополнительного члена экипажа не оборудовано системой ручного стопорения ремней, стопорение выполняется автоматическим инерционным механизмом.

- КОМАНДУ«ЭВАКУАЦИЯ, ЭВАКУАЦИЯ» ....ПОДАТЬ

ПРОЦЕДУРЫ ДЛЯ КАБИННОГО ЭКИПАЖА

Примечание : Команду начать эвакуацию подает летный экипаж, но, если связи с летным экипажем нет и достоверно известно, что выполнить эвакуацию необходимо, любой член кабинного экипажа может инициировать эвакуацию.

Каждый член кабинного экипажа должен действовать в соответствии со следующими процедурами:

■ **По команде «ЭВАКУАЦИЯ, ЭВАКУАЦИЯ»:**

- ВСТАТЬ И КОМАНДЫ «ЭВАКУАЦИЯ, ЭВАКУАЦИЯ», «РАСТЕГНУТЬ ПРИВЯЗНЫЕ РЕМНИ» ....ПОДАТЬ
- КОМАНДЫ «ТУФЛИ НА ВЫСОКИХ КАБЛУКАХ СНЯТЬ», «ВЕЩИ НЕ БРАТЬ» ....ПОДАТЬ
- ВНЕШНИЕ УСЛОВИЯ НА БЕЗОПАСНОСТЬ.............................ПРОВЕРИТЬ

  Перед открытием двери через смотровое окно или ближайший к двери иллюминатор убедиться в отсутствии сильного задымления, открытого огня и других препятствий в зоне эвакуации. Аварийный осветительный фонарь используйте в темное время суток

- **Если внешние условия не безопасны:**
  - ПАССАЖИРОВ К БЛИЖАЙШЕМУ ДОСТУПНОМУ АВАРИЙНОМУ ВЫХОДУ..НАПРАВИТЬ
  - НЕДОСТУПНЫЙ ВЫХОД ....ОХРАНЯТЬ

12	A-17	EMERGENCY AND ABNORMAL PROCEDURES	AEROFLOT Russian Airlines RRJ-95
	05.90	PASSENGERS AND CREW EVACUATION	Quick Reference Handbook

EVACUATION ON LAND

PROCEDURES FOR THE FLIGHT CREW

- **On command «ATTENTION! LANDING»**

– BELT LOCKING HANDLE TO THE MAN LOCKING POSITION……………………………SET

Note: *The jumpseat is not equipped with the manual belt locking system, the locking is enabled with the automatic inertial mechanism.*

– «EVACUATION, EVACUATION» COMMAND……………………………………………… GIVE

PROCEDURES FOR THE CABIN CREW

Note: *The command to initiate the evacuation is given by the flight crew, but if there is no contact with the flight crew and it is reliably known that the evacuation is required, the evacuation may be initiated by any cabin crewmember.*

Each cabin crewmember shall act compliant to the following procedures:

■ **On command «EVACUATION, EVACUATION»**

– STAND UP AND «EVACUATION, EVACUATION», «SEAT BELTS OFF» COMMANDS..GIVE

– «REMOVE HIGH-HEELED SHOES», «LEAVE EVERYTHING» COMMANDS……………GIVE

– EXTERNAL ENVIRONMENT SAFETY……………………………………………………CHECK

Before open the door through the door window or the cabin window, nearest to the door, make sure that there is no heavy smoke, open flame and other obstacles inside the evacuation zone. Use the emergency flashlight in the dark.

- **If the external environment is not safe**

– PASSENGERS TO THE NEAREST ACCESSIBLE EXIT………………………..GUIDE

– INACCESSIBLE EXIT…………………………………………………………….GUARD

1.18.11 The Flight Attendant Manual, the features of the land evacuation

АЭРОФЛОТ Российские авиалинии	РУКОВОДСТВО ДЛЯ БОРТПРОВОДНИКОВ Специальная часть ВС RRJ-95	РД-ГД-027 Часть 2 Изд. 02 Рев. 02

7.3. Проведение эвакуации

Особенности эвакуации на сушу

1. После остановки ВС и команды КВС **PASSENGER EVACUATION!** членам кабинного экипажа подать пассажирам ***первый блок команд*** (допустимо использовать мегафон):

ПЕРВЫЙ БЛОК КОМАНД	
РАССТЕГНУТЬ РЕМНИ!	**SEAT BELTS OFF!**
ОСТАВИТЬ ВСЕ!	**LEAVE EVERYTHING!**
НА ВЫХОД!	**GET OUT!**

Подойти к аварийному выходу, оценить ситуацию снаружи ВС, проверить положение двери (ARMED), принять решение об использовании выхода.

- Если выход использовать можно и аварийный трап наполнился, подать ***второй блок команд***:

ВТОРОЙ БЛОК КОМАНД	
КО МНЕ! ПРЫГАЙТЕ!	**COME THIS WAY! JUMP!**
СЪЕЗЖАЙТЕ! УБЕГАЙТЕ!	**SLIDE! RUN AWAY!**

- Если выход использовать нельзя – необходимо направить пассажиров к используемым выходам:
  - повернуться лицом к пассажирам;
  - заблокировать выход и подать команды:

ВЫХОДА НЕТ!	**EXIT BLOCKED!**
БЕГИТЕ К ДРУГОЙ ДВЕРИ!	**USE OTHER EXIT!**

  - держать пассажиров на расстоянии вытянутой руки, чтобы не ограничивать свою свободу движения.

2. Начать эвакуацию через противоположный аварийный выход, если:
   - член кабинного экипажа отвечает за две двери;
   - член кабинного экипажа, отвечающий за противоположный выход, не в состоянии это сделать.
3. После эвакуации пассажиров проверить пассажирскую кабину и убедиться, что на борту ВС никого не осталось (СБ и бортпроводник 1R проверяют кабину летного экипажа).
4. Взять необходимое для организации выживания аварийно-спасательное оборудование (мегафон, фонарь, аптечку, радиобуй).
5. Эвакуироваться, собрать пассажиров на безопасном расстоянии от ВС, оказать первую помощь раненым.

AEROFLOT Russian Airlines	**FLIGHT ATTENDANT MANUAL** **The RRJ-95 aircraft special section**	**РД-ГД-027** Part 2 Ed. 2 Rev. 02

7.3. Evacuation

The features of the land evacuation

1. After the aircraft stop and the **PASSENGER EVACUATION!** command by the PIC the cabin crewmembers shall give ***the first block of commands*** to the passengers (it is acceptable to use the megaphone):

FIRST BLOCK OF COMMANDS
SEAT BELTS OFF! **LEAVE EVERYTHING!** **GET OUT!**

To come to the emergency exit, evaluate the environment outside the aircraft, check the door position (ARMED), make the decision on the use of the exit.

- If the exit may be used and the escape slide has been inflated, give ***the second block of commands***:

SECOND BLOCK OF COMMANDS
COME THIS WAY! JUMP! **SLIDE! RUN AWAY!**

- If the exit cannot be used – the passengers should be guided to the available exits:
  - to face about passengers
  - to block the exit and give the commands

EXIT BLOCKED! **USE OTHER EXIT!**

  - to hold passengers at arm's length so as not to restrain oneself

2. To initiate the evacuation through the opposite emergency exit, if:

- a cabin crewmember is in charge of two doors;
- a cabin crewmember in charge of the opposite exit is unable to do it.

3. After the passengers evacuation inspect the passenger cabin and make sure no one remained on board (the chief flight attendant and 1R flight attendant are to inspect the cockpit).
4. To take the required survival emergency and rescue equipment (the megaphone, flashlight, first aid kit, beacon)
5. To evacuate, gather the passengers at the safe distance off the aircraft, to provide first aid to the injured people.

1.18.12 The definitions of the in-flight failure conditions according to AR-25

AR-25, the Definitions section

The failure condition (effect) – the condition, arising in-flight under the effect of the adverse factors or their combination and resulting in degraded safety of the flight. The failure conditions (effects) are classified by the following criteria:

(a) The degradation of the performance, the stability and controllability, structural integrity and the systems operational characteristics.

Note: the flight is regarded from the point of the start of the aircraft movement along the runway at takeoff up to the runway vacation after aircraft landing or stop.

(b) The increase in the crew workload/physiological load beyond the normally acceptable level.

(c) Discomfort, injury or death of the people on board.

The failure conditions, as for the degree of their hazard, fall into:

(a) Catastrophic (the catastrophic effect) – the failure condition, as for which it is explicitly acknowledged that at its onset the prevention of the people’s fatalities is practically impossible.

(b) Hazardous (the hazardous effect) – the failure condition, specified by:

(i) the significant degradation of the performance and (or) reaching (exceedance) of the extreme limits; or

(ii) the physical fatigue or such a crew workload that it cannot be relied on in terms of the performance of its tasks in an accurate or complete way.

(c) Major (the major effect) – the failure condition, specified by:

(i) a noticeable degradation of the performance and (or) one or several parameters going beyond the operational limitations, but without reaching the extreme limits; or

(ii) the degradation of the crew’s potential to handle the adverse conditions (the arising situation) due to the both increase of workload, and the environment, reducing the efficiency of the crew actions.

(d) Minor (the minor effect) – the failure condition, specified by:

(i) slight degradation of the performance; or

(ii) a marginal increase of the crew workload (for example the change of the flight plan).

1.18.13 The FAR-121 provisions on the flight crew extended envelope training

FAR-121.423 – Pilot: Extended Envelope Training

(a) Each certificate holder must include in its approved training program, the extended envelope training set forth in this section with respect to each airplane type for each pilot. The extended envelope training required by this section must be performed in a Level C or higher full flight simulator, approved by the Administrator in accordance with § 121.407 of this part.

(b) Extended envelope training must include the following maneuvers and procedures:

(1) Manually controlled slow flight;

(2) Manually controlled loss of reliable airspeed;

(3) Manually controlled instrument departure and arrival;

(4) Upset recovery maneuvers; and

(5) Recovery from bounced landing.

(c) Extended envelope training must include instructor-guided hands on experience of recovery from full stall and stick pusher activation, if equipped.

(d) Recurrent training: Within 24 calendar months preceding service as a pilot, each person must satisfactorily complete the extended envelope training described in paragraphs (b)(1) through (4) and (c) of this section. Within 36 calendar months preceding service as a pilot, each person must satisfactorily complete the extended envelope training described in paragraph (b)(5) of this section.

1.18.14 The FBWCS operational modes at the RRJ-95 aircraft

The aircraft flight control system is an electronic fly-by-wire control system (FBWCS) without mechanical linkage of the aircraft flight controls, installed in the cockpit, to the high-lift devices.

Pilots with the use of the flight controls in the cockpit – the sidesticks and pedals – control the aircraft in pitch, roll and yaw.

The processing segment of the FBWCS processes the signals, transmitted by the sensors of the system itself and of the aircraft interacting systems, computes the control commands, consistent with which the flight controls' actuators set the aerodynamic surfaces in the target position to proceed the flight along the estimated path, while ensuring inter alia:

– the optimization of the characteristics of the aircraft stability and controllability into the entire expected operational envelope;

– the automatic operational envelope limits protection in AOA, pitch, roll, as well as IAS, Mach number and acceleration;

– the automatic stabilization of the pitch and roll, reached by the point of the sidestick pressure release at the manual operation of the aircraft, including automatic pitch trim;

– automatic turn coordination.

The performance of these functions is distributed between the control system processors and the actuator control units as follows. Three PFCU computers ensure the FCS interface with the other aircraft systems to perform the NORMAL MODE functions.

Fourteen ACE units enable:

- the transmission of signals from the flight control sensors to the PFCU;
- the control of the flight control surfaces actuators by the PFCU signals;
- the direct actuator control by the signals from the flight control sensors in DIRECT MODE.

Each ACE unit controls one electrohydraulic actuator, installed on the aircraft flight control surfaces – the elevators, ailerons, spoilers and rudder.

Six Motor Actuator Control Electronics/MACE enable:

- the control of the stabilizer and wing high-lift devices electric actuators by the flight control signals together with the PFCUs;
- the direct control of the stabilizer and wing high-lift devices electric actuators by the flight control signals in DIRECT MODE.

The FBWCS integrates three operation modes: NORMAL MODE, simplified mode[83] and DIRECT MODE. The switch from one mode to another occurs automatically, being shockless.

Normal Mode

The mode is engaged subject to the availability of all required data from interacting aircraft systems and under the proper operation of at least one PFCU. The PFCU signals are transmitted to the ACE units, which control the corresponding flight control surface actuators. The aircraft is controlled both in manual and automatic mode. When the aircraft is on ground as for the NORMAL MODE the roll and pitch stabilization modes are disengaged, the stabilizer is controlled manually.

Minimum mode (Direct Mode)

The FBWCS reverts to the minimum mode (DIRECT MODE) at the loss of the signals from all the ADC or IRS or at the failure of three PFCU computers. All the events of the FBWCS reversion to DIRECT MODE are addressed in the operational documentation. At that the aircraft stability and controllability characteristics to the acceptable level are ensured, being sufficient for the safe completion of the flight.

The FBWCS limit functions, the functions of the current pitch and roll stabilization, as well as the automatic turn coordination are not enabled in DIRECT MODE. The trim is accomplished manually. The aircraft control is carried out in a manual mode only. At that the electric signals, proportional to the aircraft sidestick and pedals deflection angles, are delivered through the ACE units to the corresponding control surfaces actuators, without passing through PFCU computers.

Two RSUs deliver the data to the ACE units to ensure the target characteristics of the aircraft damping in DIRECT MODE.

[83] It is not addressed in the subject Report.

If the FCS reverted to DIRECT MODE, it is impossible to switch it back to NORMAL MODE in-flight.

Note: *According to the information, submitted by the aircraft designer, the set of the functions of the alternate control modes for all aircraft, certified in compliance to AR-25 (CS-25, FAR-25), is determined by the fail-safety criteria, set out in the aviation regulations, uniform to all the aircraft types. In accordance with the fail-safety analysis that is based on the uniform criteria to all the aircraft types, the uncontrolled motion of the flight controls is evaluated as the CATASTROPHIC FAILURE CONDITION. Unless the NORMAL MODE algorithms feature the correction of the commands, transmitted to the flight controls by the external reference systems indications (ADS and IRS), then the FBWCS integrates the multisampling SBITE as to all the input signals out of these systems, including with the use of the independent datalink.*

If there is a reasonable doubt about the validity of the data out of the external reference systems, the FBWCS may be reverted to DIRECT MODE even at the serviceable condition of its processors. The in-flight resumption of NORMAL MODE after the FBWCS reversion to DIRECT MODE is only possible when there is a 100 % certainty in the proper operation of both the FBWCS processors and the external reference interfaces after the recorded failure. At that due to the complexity of its algorithms the resumption of the NORMAL MODE is only ensured in the stabilized horizontal flight outside the turbulence area. In view of the complexity of combining these factors, to meet the certification requirements at the system design stage it had been decided that the in-flight NORMAL MODE reboot was not enabled.

1.18.15 The RRJ-95 aircraft flight control system architecture philosophy[84]

Pitch channel

Irrespective of the type of the flight control system and the aircraft type, the control of the vertical flight path is done due to the change in the normal acceleration. Changing the pitch attitude without changing the normal acceleration does not result in the change of the flight path angle, vertical speed and, accordingly, the flight altitude.

[84] This Section only outlines the control system functions that are essential to **understanding** the Report.

The aircraft normal acceleration is controlled with the elevator deflection, which results in the rise of the pitch angular rate, the change of the AOA, lift and consequently, the increment of the normal acceleration.

It is known that depending on the airspeed the pilot's perception of the aircraft response to the elevator deflection is varied. This is because at the flight at the high and low airspeeds the AOA increment, required to establish the equal increment of the vertical acceleration, is significantly different. At that the required elevator deflection to change the AOA by a constant is hardly affected by the airspeed.

Note: *For the airplane with the wing surface of 84* m^2*, the airspeed of 250 kt, the weight of 35000 kg the lift coefficient as for the level flight is CL= 0.4. To establish the acceleration increment, equal to dny = 0.3 it is required to increase Cy by 30 %, that is* $\Delta Cy = 0.12$*. Taking the derivative of the lift coefficient from the AOA change* $Cy^{\alpha} \cong 0, 1$ *we get the required increase of the AOA* $\Delta\alpha = 0.12 / 0.1 = 1.2°$*.*

At the flight at the V = 130 kt at the same weight and configuration CL is already equal to 1.49, that is at the same value of the required increment of acceleration the increase will be required of $\Delta Cy = 0.45$*, which requires the AOA change by* $\Delta\alpha = 0.45 / 0.1 = 4.5°$*, i.e. 3.7 times more.*

Consequently, from the point of view of the pilot's perception, at the flight at high airspeeds the control handle deflection results first in the onset of acceleration and then in the change of the aircraft attitude, mostly due to the increment of the flight path angle and conversely at the low airspeeds.

The statically stable – in terms of acceleration – aircraft has the property to restore the acceleration value, achieved in a trimmed flight with a constant airspeed after the acceleration increment effect is no longer present, no matter this increment had been caused by the external effect or the elevator deflection off the trim. This property manifests itself in the aircraft, maintaining constant AOA and pitch at the flight with the constant speed and after changing the flight path angle no extra trim is required, if this is not caused, for instance, by the significant change of the engines power rating. That is to say as for the statically stable aircraft its natural pitch attitude stabilization is ensured at the control handle release (the sidestick pressure release).

The statically stable – in terms of airspeed – aircraft has the property to restore the airspeed value, established in the trimmed flight, after the airspeed disturbance is no longer present. With no change of the engines power rating it is achieved as the increase of airspeed under the external disturbance the normal acceleration increment leads to the aircraft transition in climb and, accordingly, to the incipient tendency to the airspeed reduction and at the disturbance, resulting in the decrease of IAS, the aircraft transits in the accelerated descent. This behavior naturally causes the aircraft to return to the trim airspeed value.

It is these principles, the philosophy of the RRJ-95 aircraft FBWCS control law in pitch, irrespective of the flight control system operation mode, rests on. From the pilot's point of view at high speeds the airplane responds to the sidestick deflection with the increment of normal acceleration, at low speeds it does with the pitch attitude change. At the sidestick pressure release after the full trim of the airplane in pitch the airspeed statically stable airplane response, natural to the pilot, is ensured.

At the FBWCS operation in NORMAL MODE these principles are achieved by the Sidestick deflection – Target acceleration integral control law at the high airspeeds, which gradually becomes the Sidestick deflection – Target AOA integral control law with the AOA increase (either at the airplane deceleration, or at the dynamic maneuvering). The airspeed stability, apart of the aircraft inherent performance, is ensured by the feature of the pitch attitude stabilization at the sidestick release. The elevator trimmed position, accumulated as the output of this function, is deducted under the auto balance (trim) function due to the stabilizer deflection to zero position and thus ensuring the appropriate aircraft pitch trim into the entire flight.

In terms of mathematics the total command signal to the elevator surfaces consists of 8 elements:

elv_dmd = dv_pr + dv_nywz_p + dv_alfa_p + dv_alfa_lim_p+ dv_weight + dv_teta_p + dv_tail + dv_int

Over here:

dv_pr – the direct control command signal that determines the magnitude of the elevator deflection in proportion to the sidestick deflection. Essentially this is a direct analogue of the elevator command, adjusted for the sidestick total gain in pitch at the FBWCS operation in DIRECT MODE. Its (the sidestick total gain in pitch) value is optimized against the IAS and adjusted to the aircraft CG position, determined by the stabilizer trim position;

dv_nywz_p – the sum of the acceleration and pitch rate feedback signals;

dv_alfa_p – the AOA feedback signal;

dv_alfa_lim_p – the AOA limit function feedback signal;

dv_weight – the weight component feedback signal of the AOA derivative, which is accomplished at the AOA, close to the limit;

dv_teta_p – the pitch feedback signal out of the positive pitch attitude limit function;

dv_tail – the protection algorithm signal of the tail strike against the runway at takeoff;

dv_int – the integral control loop signal.

All the elements, except of the last one, are generated in the control laws nonintegral circuits.

As the elevator command is determined by the sum of the components, computed in different algorithm branches, the slope of the dependence of the elevator deflection angle vs the sidestick deflection is only affected by the non-linear conversion of the sidestick command signal and the components of the dv_pr parameter. The remaining components of the control law lead only to a linear shift of this parameter without changing the gain in the Pilot – FBWCS – Airplane path.

The generated command signal is processed by the control surface actuator, which, through a mechanical link, deflects the elevator to the position, consistent with the command signal. As for the flight in NORMAL MODE the RRJ-95 airplane does not integrate the FLARE specific mode, which is the case at the Airbus aircraft. Instead of the FLARE mode in order to prevent the integral loop operation, being negatively affected by the ground effect, resulting, in particular, in high flare provocation, the value of the integral component of the elevator command signal is frozen at the true altitudes below 50 ft (15 m), determined by the radio altimeter. Thereby at the altitudes below 50 ft at the FBWCS in NORMAL MODE as for the pitch channel the control law is accomplished, being fundamentally close to the control law in DIRECT MODE (see this Section text here below). In the circumstances under consideration of the flight that ended up with the accident this very law may be simply represented as:

$dv = Cgain*Xv + Cw_z*w_z$,

Over here:

dv – elevator deflection;

Xv – the sidestick deflection in pitch;

Cgain – the sidestick total gain in pitch;

Wz – pitch rate;

Cw_z – the pitch damp channel gain.

The operation of the sidestick – elevator path in the FBWCS DIRECT MODE

At the FBWCS DIRECT MODE the acceleration and airspeed static stability of the aircraft are ensured through the selection of the horizontal empennage dimensions and the determined CG limitations. Due to this the RRJ-95 aircraft has sufficient inherent stability in pitch and does not require the integration of the augmentation automated means.

The architecture of the RRJ-95 aircraft FBWCS computer complex is so structured that to completely eliminate the risk of generating spurious signals out of the FBWCS NORMAL MODE algorithms. Therefore at the onset of the internal faults, or these of the data sources, important for the reliable operation of NORMAL MODE, the upper level computers (PFCU), which integrate the NORMAL MODE algorithms, are completely disconnected from the low level ACE/MACE computers that are directly linked with the flight controls in the cockpit and the elevator, stabilizer surfaces and high-lift devices of the aircraft. To ensure the satisfactory handling qualities, including in terms of no PIO, at the flight in DIRECT MODE the back-up RSUs had been introduced in the FBWCS equipment, which are used for the additional pitch, roll and yaw damping.

At the FBWCS in DIRECT MODE the manual control is only ensured. The position sensor signals to each control handle are delivered to the ACE of the corresponding actuators. At the elevator ACE the signals out of the sidestick are transduced to the command signals to deflect the control surfaces by the law as follows (with no regard for the elastic mode filter operation):

$$\delta_{elev} = f\text{Cnonlin\_elev}\,(X_{elev}) * C_{gear}(\delta_{fl}) * \text{WXelev}(s) + C\omega z * \omega_{z\_limit},$$

where:

$-7°/\text{sec} \le \omega z_{\_limit} \le 7°/\text{sec}$ – pitch rate;

$C\omega z = 1$ – pitch rate damping.

$-120\text{ mm} \le X_{elev} \le 120\text{ mm}$ – the sidestick deflection in millimeters (the degrees to millimeters conversion factor C = 120/13.7);

$\text{WXelev}(s) = \frac{1}{0.1s+1}$ – an aperiodic filter with a time constant of 0.1 sec, through which the sidestick deflection signal is passed at the generation of the elevator command signal. The filter is designed for the handling qualities augmentation, as estimated by the pilot;

$Cgear\,(\delta_{fl})$ – the gearing, depending on the flaps position that is introduced in DIRECT MODE to optimize the handling qualities vs the airspeed:

δ_{fl}, deg.	0	3	9	16	25	36
$Cgear(\delta_{fl})$, deg/mm	0.14	0.14	0.14	0.19	0.225	0.225

ƒCnonlin_elev(Xelev) – the nonlinear dependence of the sidestick pitch signal (see the Table here below and

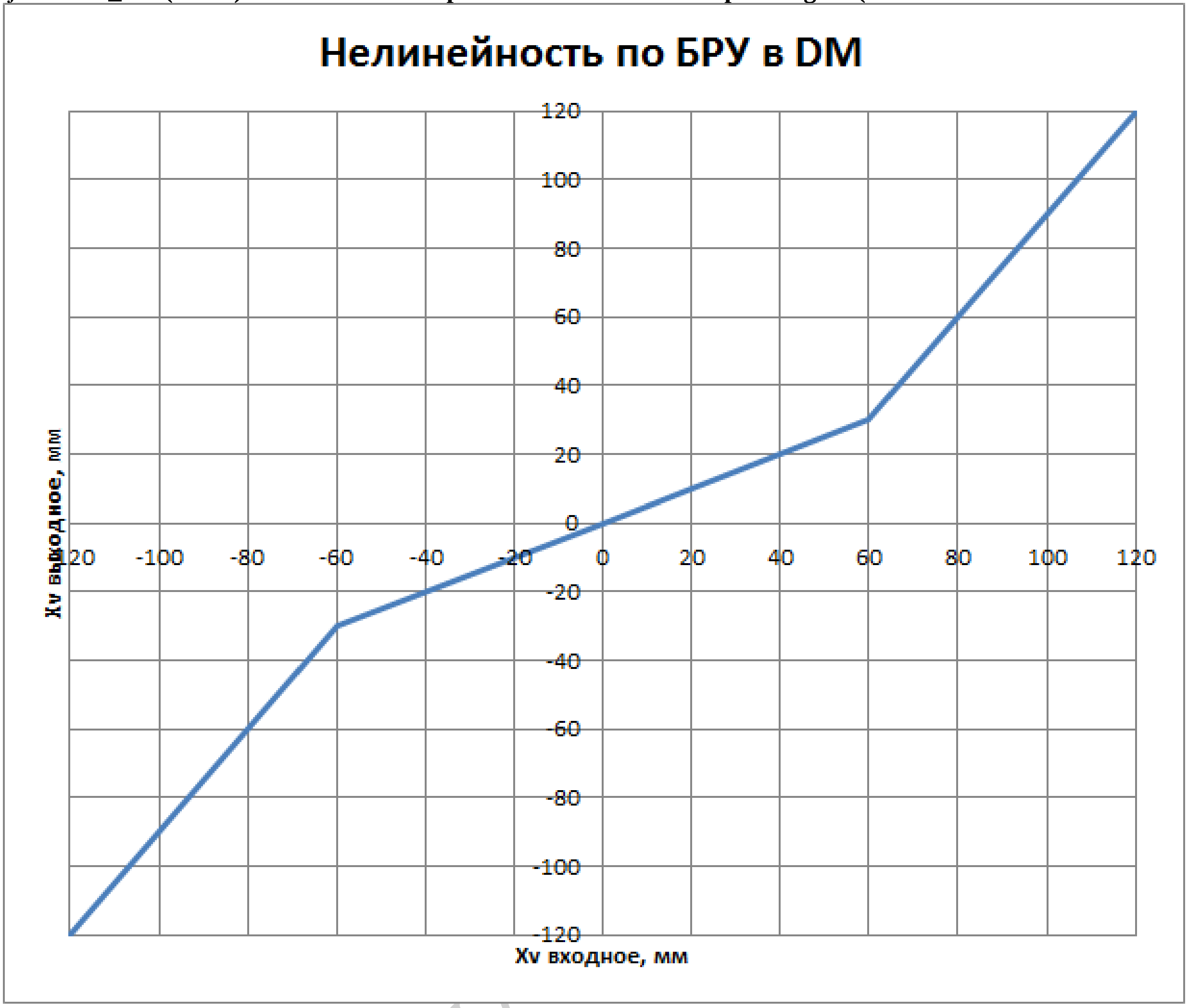


Fig. 120), selected to maintain the high level of scaling of the aircraft response to the sidestick deflection. This dependence integrates a specially selected nonlinearity, the slope of which in a region of the precision piloting (± 50 % of the sidestick travel) is selected by the simulation in NORMAL MODE for the mean CG. Beyond this range the slope is selected on the condition to achieve the maximum elevator deflection angle to ensure the maximum control authority in pitch that may be required to perform go-around, avoid the collision, recover the aircraft out of approach to stall and upset.

X_{elev}, mm	-120	-60	0	60	120
ƒCnonlin_elev(X_{elev}), mm	-120	-30	0	30	120

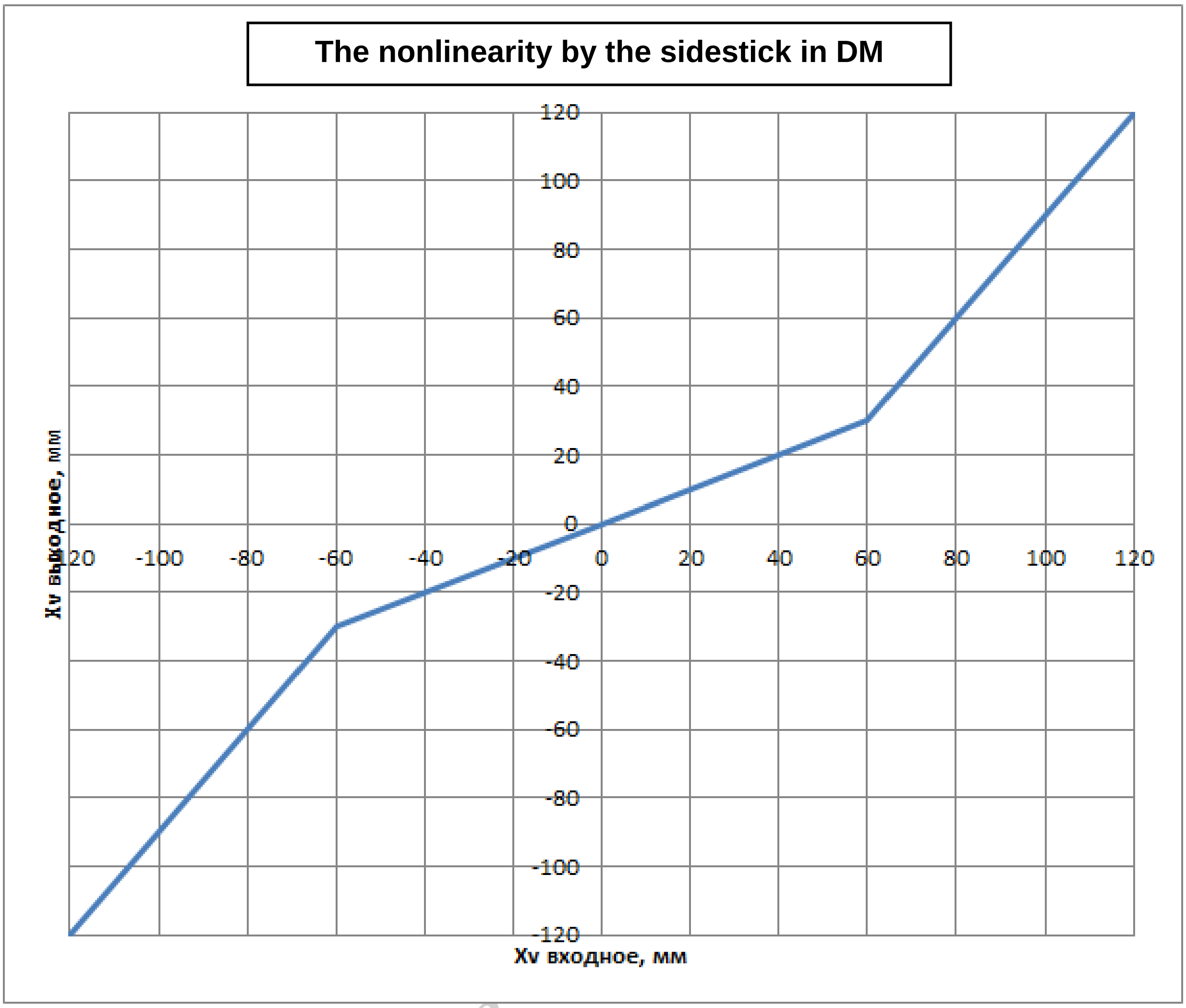


Fig. 120. The sidestick input and output signal dependence in DM

Thus, at the true altitudes below 15 m (50 ft) at both FBWCS operation modes (NORMAL MODE and DIRECT MODE) the fundamentally close control laws are accomplished that to a first approximation may be represented as follows: $\delta_{elev} = C_{gain\Sigma}(\delta_{fl})*Xelev + K\omega z*\omega_z$. The actual differences in control laws consist in the different gain and damping ratios.

This way, as for the FBWCS DIRECT MODE in a FLAPS 3 configuration ($\delta_{fl} = 25^0$) the total gearing ratio from the sidestick to the elevator surfaces ($Cgear_\Sigma$) is equal to the product of nonlinearity Cnonlin_elev (X_{elev}) by the the gearing, depending on the flaps position Cgear(δ_{fl}). This leads to the nonlinear dependence of the total ratio $Cgear_\Sigma$ as for the sidestick deflection. Into the landing environment in the flight that ended up with the accident at the sidestick deflection within a range of up to ½ of full travel (the basic control envelope) the total control ratio amounts to $Cgain_\Sigma = 0.112$. At the sidestick deflection beyond the half-travel the gain ratio is nonlinearly increased to ensure the capability of the full deflection of the elevator. As for the FBWCS NORMAL MODE the respective gain ratio is $Cgain\Sigma = 0.1$.

The damping ratios Cωz are equal to «2» and «1»[85] for NORMAL MODE and DIRECT MODE respectively. This means that at the FBWCS in NORMAL MODE the angular motion of the airplane is of a large ***additional*** damping. At that the basic damping of the aircraft oscillations in pitch is done naturally by the aerodynamic forces and, as the airplane has good inherent damping performance in pitch channel, the subject differences only manifest themselves at high pitch rates. Apart of this, as indicated above, the pitch rate limits are introduced into the control law. Similarly as for NM there is a normal acceleration feedback, which is still present even at the frozen integral loop.

To trim the aircraft in pitch in DIRECT MODE the stabilizer control should be used, which is located at the cockpit central pedestal trim control panel. The trim procedure to the RRJ-95 aircraft does not differ from the other aircraft where the stabilizer acts as the elevator trim (for instance, IL-76, IL-96, B737, B777, etc).

The feature of using stabilizer to trim the aircraft in pitch is that the release of the sidestick pressure is carried out by selecting the stabilizer position, at which the elevator is to be positioned zero, and not by the zeroing of the elevator hinge moment with the trim tab deflection or the shift of the feel springs at the airplanes with the power-controlled system and trim effect simulator in the elevator channel. When trimming the aircraft by stabilizer the pilot should select the stabilizer position, concurrently repositioning the sidestick to neutral in pitch, i.e. releasing the pressure on it. The trim is considered fully completed, when at the sidestick in neutral position (the released back pressure) the airplane maintains the in-flight target flight path angle.

Roll channel

The aircraft flight control dynamics in the roll channel differs from the control dynamics in the pitch channel. The roll rotation of the aircraft is a consequence of the roll angular rate onset, which is created using the control surfaces, mounted on the wing panels: the ailerons and spoilers. Besides, the sweptwing and anhedral aircraft feature the noticeable response in roll channel to the onset of slip, resulting from high stability in roll to this type of aircraft. This aircraft property is manifested at the generation of the slip in the onset of the rolling towards the retreating half-wing.

The selection of the parameters of the RRJ-95 aircraft vertical empennage is made in such a way that to ensure the aircraft spiral stability through a good balance between the static stability in yaw and in roll. This implies that after the aircraft enters the steady turn and the pressure on the sidestick and pedals are released the airplane clearly tends to decrease the roll with rolling out the turn. This property of the airplane ensures a good stability into the target track flight, both in calm and turbulent air. That is to say to proceed the turn with the constant roll it should be performed

[85] The Cwz value in DIRECT MODE is selected by the criterion of the self-oscillations prevention.

either in a coordinated manner that is by deflecting the rudder (pedals) in the direction of turn to eliminate the resulting slip, or the flight controls in roll should be kept deflected.

It is these principles of maintaining the aircraft response, natural to the pilot, to the flight controls deflection, the philosophy of the RRJ-95 aircraft FBWCS control law in roll, irrespective of the flight control system operation mode, rests on.

At the FBWCS in NORMAL MODE these principles are accomplished through the direct commands to the control surfaces from the flight controls. The feedback and cross-coupling are introduced for solving the tasks of the automatic turn coordination into the entire roll envelope, the bank control at the sidestick release and the thrust asymmetry compensation.

Mathematically, the command to deflect the ailerons in the roll channel is described as:

del = de_direct + de_wx + de_yaw + de_spiral+ de_hold + de_apod + de_trim

Over here:

de_direct – the command signal by the pilot;

de_wx, – the roll damper feedback;

de_yaw – the signal of cross-coupling with the yaw channel;

de_spiral – the roll limit function component;

de_hold – the component of the bank control. The integral signal;

de_apod – the component of the thrust asymmetry compensation;

de_trim – command in roll channel from the trim control panel.

At that, similar to the pitch channel, the only one component (de_direct) determines the slope of the Cgain parameter, the remaining ones ensure its linear shift by summing up of their components with the basic command.

The spoilers operate together with the ailerons, the deflection of which is done by the law as follows: dint_Xe = Ksh_in*dint_el.

Over here:

Ksh_in – the ratio of the command signal transmission to the spoilers;

dint_el – the command to deflect the spoilers in proportion to the ailerons deflection angle. It has the dead area of about up to 30 % of the ailerons travel.

In DIRECT MODE the control law is alike given there are no automatic turn coordination, bank control at the sidestick release and automatic thrust asymmetry compensation functions. Mathematically it is represented as:

$\delta_{ail} = f Cnonlin\_ail(X_{ail}) * WX_{ail}(s) * C_{gear}(\delta_{fl}) + Wwx(s) * C\omega x(\delta_{fl}) * \omega_{x\_limit} + \delta_{ail\_trim}$.

Over here:

$f Cnonlin\_ail(X_{ail}) * WX_{ail}(s) * C_{gear}(\delta_{fl})$ – the sidestick command to deflect ailerons;

$Wwx(s) * C\omega x(\delta_{fl}) * \omega_{x\_limit}$ – the roll damper feedback;

δ_{ail_trim} – the trim control panel command.

As there is no data exchange in DIRECT MODE, which is accomplished in the PFCU, it is the sidestick deflection that determines the command to deflect the spoilers, and not the ailerons. Still, similar to NORMAL MODE, this command has a dead area at about the same sidestick travel in roll.

The automatic turn coordination function

A proper coordinated turn implies the banked flight at the constant altitude and with the near-zero slip angle.

To accomplish the function of the turn coordination two tasks are solved in the FBWCS laws:

1. Into the banked flight the normal acceleration is increased by the value, equal to $1/\cos(\gamma)$.
2. The rudder is deflected by a certain amount, ensuring the near-zero slip angle.

The first task is solved in the elevator control channel in the position feedback loop, in which the component of the elevator command signal is generated that contains the normal acceleration and pitch rate signals with the ratios, adjusted to the flight parameters.

The second task is solved in the rudder control channel in the feedback loops by the slip angle derivative and lateral acceleration.

1.18.16 General description of the aircraft fuel system

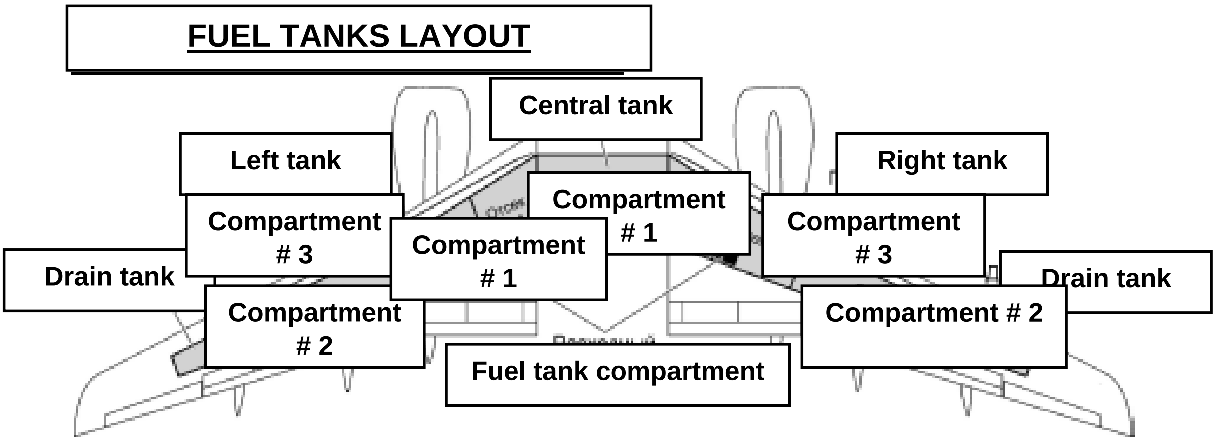
Aboard the aircraft the fuel is placed in three fuel tanks:

– the left wing tank (it is integrated in the left wing panel);

– the right wing tank (it is integrated in the right wing panel);

– the center tank (it is integrated in the center fuselage).

Fig. 121 shows the tanks layout to the aircraft and their maximum fuel capacities.



ВМЕСТИМОСТЬ ТОПЛИВНЫХ БАКОВ

Топливные баки		Объем, л	*Масса, кг
Левый крыльевой бак	Отсек №2	1660	1295
	Отсек №3	1350	1053
	Расходный отсек	135	105
	Отсек №1	1925	1501
Центральный крыльевой бак		5665	4419
Правый крыльевой бак	Отсек №1	1925	1501
	Расходный отсек	135	105
	Отсек №3	1350	1053
	Отсек №2	1660	1295
ВСЕГО		15805	12327

*Верно для плотности топлива 0,78 кг/л

Свободный объем надтопливного пространства составляет ~ 4,4%

Fig. 121. The layout and capacity of the fuel tanks to the RRJ-95 aircraft

THE CAPACITY OF THE FUEL TANKS

Fuel tanks		Capacity, liters	*Weight, kg
Left wing tank	Compartment # 2	1660	1295
	Compartment # 3	1350	1053
	Fuel tank compartment	135	105
	Compartment # 1	1925	1501
Central wing tank		5665	4419
Right wing tank	Compartment # 1	1925	1501
	Fuel tank compartment	135	105
	Compartment # 3	1350	1053
	Compartment # 2	1660	1295
TOTAL		15805	12327

*True of the 0.78 kg/l fuel density

The ullage amounts to ~ 4.4 %

To feed the engine the fuel is supplied from the fuel tank compartment.

The second and third compartments are the communicating vessels, linked from below by the check valve of a 70 mm diameter (the fuel flow is oriented towards compartment 3), and from above by the interstringer gaps. Relative to compartments 2 and 3 the fuel tank compartment is located at the bottom of the outer wing, in between compartments 1 and 3. By design the fuel tank compartment is connected to compartment 3 along the upper interstringer openings and check valve of a 70 mm diameter (the fuel flow is oriented to the fuel tank compartment). The fuel system architecture and fuel management schedule out of the compartments enables the full fueling in fuel tank compartment all through the fuel is supplied to the powerplant.

By the command to shut the engines down the signal is generated to close the fuel system valves that supply the fuel to the powerplant, thereby shutting the fuel off the engines.

The principle and algorithms of the fuel quantity measurement system operation

The principle of calculation of the fuel quantity in each compartment is based on the calculation of the arithmetic mean out of the sum of the indications by all the active capacitors in the compartment.

Each compartment has its own determined number of capacitors, which allow to determine the fuel quantity into the entire operational envelope of the aircraft with the required reliability and accuracy.

This way, compartment # 3 integrates 3 capacitors (J1, J2, J3), in the fuel tank compartment one capacitor is installed (Fig. 122).

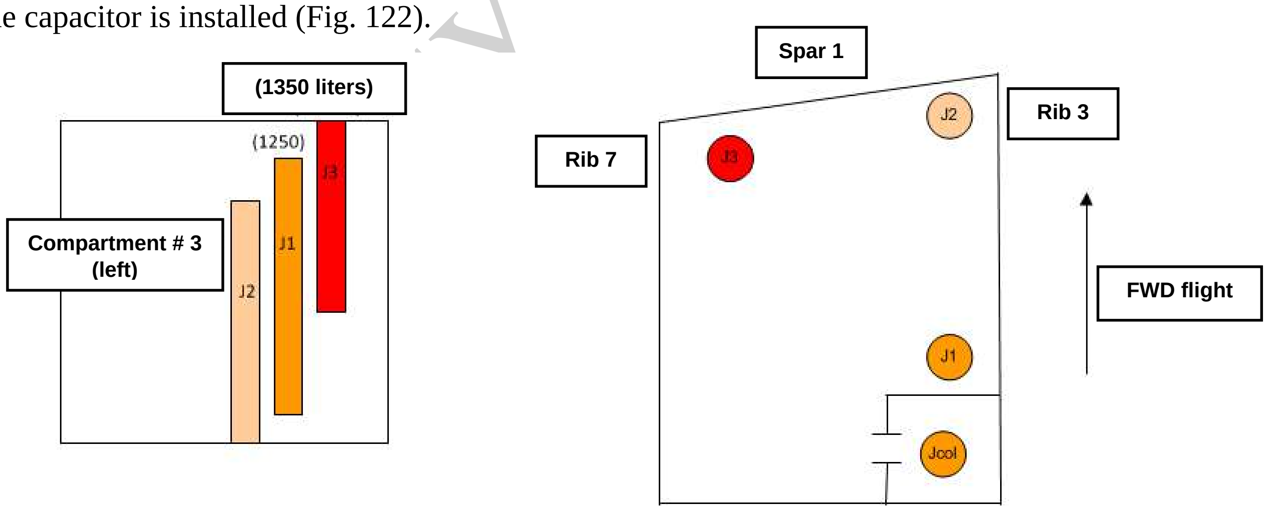


Fig. 122. The installation layout of the fuel capacitors in compartment 3 and the fuel tank compartment

The capacitors are the tube condensers. The alteration of the electrical capacitance due to the difference in the fuel and air dielectric constant ensures the computation of the capacitor immersion in the fuel, out of which the fuel quantity, measured by this capacitor, is calculated.

To calculate the fuel quantity in the tank only active capacitors indications are taken into account. A capacitor is considered active if its immersion depth is less than the installation height.

In case the immersion depth of the capacitor is greater than its installation height, then it is considered «submerged» and the computation is proceeded by the remaining active capacitors. If all the capacitors into the compartment are considered submerged then the compartment is considered completely full. Fig. 122 presents the relative heights and the regions of the capacitors installation, illustrated by the left outer wing.

The calculation of the fuel quantity and the health monitoring of each capacitor is enabled by the two-channel FQIC that calculates the fuel quantity in each tank and sends the data to the indication, warning, record interconnected systems.

The record of the fuel quantity data is enabled by the onboard flight data recording system, the record rate is once per second.

The fuel quantity is displayed to the crew at the FUEL and EWD synoptic page (Fig. 123).

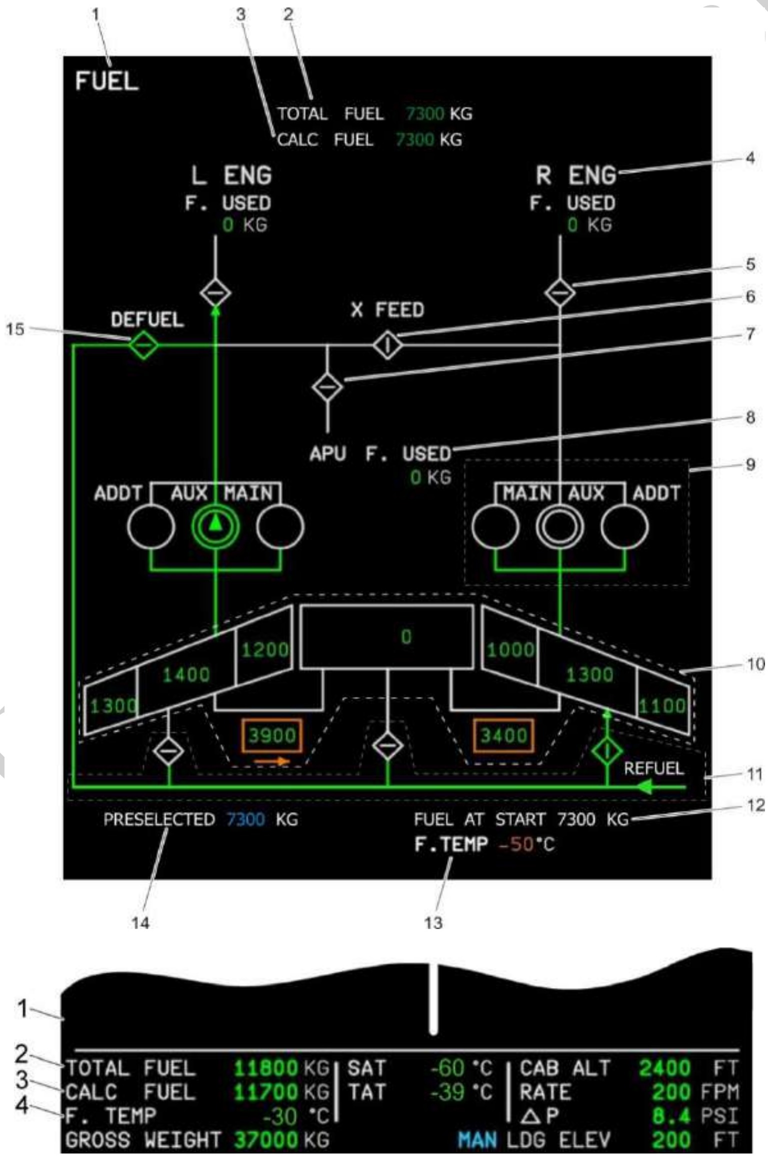


Fig. 123. The general view of the FUEL and EWD synoptic page

1.18.17 From the testimonies by the survived passengers and crewmembers

The testimonies by the survived passengers are largely consistent with each other. The passengers have noted the rapid smoke contamination of the cabin and the suffocating black smoke, having resulted in the critical incapacitation after 2-3 breaths as a determinant, having complicated the evacuation.

The evidence by the passenger, having been allocated on the 3F seat (the last Business class row), states that when he looked back, the cabin had been already filled with the black smoke and the rear section of the cabin beyond row 9 had not been visible. The 6C seat passenger said that he could not have seen anything beyond the row 11 seats. The 10A seat passenger noted that when he had been still seated, he had heard the hiss, typical of the inflating escape slide and at that point, the cabin *«had been abruptly shrouded in the thick black smoke».* The 12A seat passenger indicated that when he stood up to evacuate, the cabin had been already filled with smoke, having forced him to kneel first, lie down and crawl towards the exit afterwards. The 12C seat passenger states the similar evidence.

Only two passengers observed flame in the cabin – these two escaped aircraft the last (having been allocated on the seats 12A and 18A).

More detailed testimonies by certain passengers are given here below.

As witnessed by the male passenger, having occupied the 3A business class seat:

«The emergency exit doors were opened by the flight attendants, two women notably... None of the passengers helped the flight attendants, they managed to do it themselves... I escaped the aircraft cabin in about 30 seconds and was not helped by anyone of the cabin crew, the flight attendants (the women) verbally guided the evacuation... I was just walking to my full height, at that I was not the first to go out of the airplane, but I let people, who were walking from the back rows, advance till the moment I was able to breathe, when it became difficult for me to breathe, I escaped the cabin through the gap in between people... The visibility was normal adjacent to my seat, whereas at the back of the cabin it had been a strong smoke propagation... After the aircraft came to a complete stop I started moving towards the exit and certain passengers from the back rows started to advance towards the exit before the aircraft stopped... I went out of the airplane without belongings; my belongings had been left in the overhead bin in the aircraft cabin... It had not been much trouble for me, except for difficult breathing... The female flight attendant, who was standing next to the right exit, did not say anything, she just pushed me out of the cabin when it was my turn ... The smoke and fire appeared in about 10 – 15 second after the aircraft touched down... The panic broke out at the rear of the aircraft cabin, someone tried to call relatives, shouted «We are on fire», and some people just remained in their seats... I watched some passengers getting their belongings out of the overhead bins and walking with them along the

aisle, some belongings were impressive in size, that is they were of the maximum allowed dimensions to bring into aircraft to my mind they interfered with the passengers evacuation… The aircraft bangs against the ground were strong enough, so much that at these bangs I hit the overhead bin with my head even though I had been fastened... As far as I can remember the aircraft engines had been running till the end of the evacuation».

As evidenced by the female passenger (seat 15C):

«*It had been a rough hard landing, that is the airplane impacted the runway very hard... Although me and other passengers, seated in the tail section of the airplane, had been fastened by seatbelts, we were thrown up by the impact. After the first impact the smell of the chemical smoke could have been felt in the tail section of the cabin. By the impact the airplane was thrown up, then it impacted again and - as it seemed to me – the airplane started rolling on the airframe. After second impact the tail section of the cabin started to be filled with the black smoke. At that moment through the cabin window to my left I saw that the left wing of the airplane was in fire. After the second impact I unfastened the seatbelt and wanted to put the oxygen mask on, but it had not dropped down. I stood up from my passenger seat and first wanted to walk to the back, as there had been too much people in front, it had been a crush, because the passengers, seated in front of me, tried to take their carry-on luggage away. Still, there was even more black smoke behind my passenger seat, which made it impossible for me to see what was happening there, and I headed forward, as I did not have enough oxygen and it was hard to breathe. I cannot say if the airplane was moving along the runway at that time or had already stopped, as there was a lot of smoke, and my only goal was to get out of the cabin of the airplane... On the way to the exit I saw (Post, Surname), who was getting his carry-on luggage out from the overhead bin, thereby he prevented other passengers from advancing to the exit. Apart from (Surname), there were other passengers, unknown to me, who also took out their carry-on luggage from the overhead bins, thereby they made an impassable jam in the aisle to the exit… Behind me there had been passengers as well who were as well trying to proceed to the exit. It was hard for all the passengers to breathe because of the heavy smoke that filled the cabin of the aircraft. Further I saw a male passenger, crawling down along the aisle. I asked him why he was crawling and whether he needed assistance. He told that there was less smoke beneath. Then I ducked as well and headed to the exit. I cannot say how much time it took me to make way to the exit as I nearly fainted by then, but at that moment a blonde-haired man in an orange vest*[86]*, unknown to me, grabbed me by the hand and helped me to get out from the airplane and pushed me out on the slide. As I had gone down the slide, I was unable to get on my feet and crawled away in the opposite direction from the airplane, because*

[86] It had been the Sheremetyevo Handling, LLC employee who was wearing an orange vest and was helping passengers near the slide on ground.

someone shouted that the aircraft was about to explode.... the passengers in the back rows had no chances to evacuate due to the rapid propagation of smoke in the aircraft rear fuselage ... Passengers, allocated in the tail section of the aircraft were not alerted of the evacuation and they may have been waiting for the command and therefore remained seated».

As evidenced by the male passenger (the seat 18A):

«The aircraft landed hard... The following were two touchdowns at least, at that the last one, as it seemed to me, was on the rear section of the aircraft. After the last touchdown of the aircraft onto the runway I saw through the cabin window the left engine, having been caught on fire and almost straight away there appeared the blue-grey smoke in the tail section of the aircraft (the cabin) that began to slowly come down, the black smoke appeared afterwards... And in parallel with the black smoke I saw a flame of fire to my left (outside first) – this was the fire of the baggage compartments (in the cabin above the seats), I watched it in front of me, I believe, around row 14. Almost immediately after the third touchdown and the appearance of smoke and fire in the tail section of the cabin, it had been the onset of panic, all passengers unfastened their seatbelts even before the airplane came to a complete stop and started to make their way through the aisle to the front emergency exits... The result was the occurrence of jam in the aisle that was reaching my row. I cannot tell what were the actions by the flight attendant, allocated in the rear aircraft, as I had not seen what he was doing... As it had been hard to breathe in the tail section of the cabin because of the black smoke, I tried to make my way towards the aircraft nose. Having passed to the aisle I squatted, because there had been an acrid smoke above. Additionally I shouted to all the passengers that they ducked, as being exposed to acrid smoke one could instantly lose consciousness. At that moment my friend [Surname] yelled at me: «[Name], over here». At that moment he was squatting down next to row 17. However I had no longer been able to return back, as two women, unknown to me, were already following me and there had been a jam in the aisle. There had been less smoke in the aircraft nose and therefore the only right solution, as I thought, had been to make my way to the nose of the airplane as quickly as possible. Given that there had been a jam in the aisle I made the decision to make my way by crawling by the seats backs in the zone of the fire seat. With breathing the air in and holding the breathe I, grabbing the seat backs with my hands, started to make my way forward, at that having pushed off against the backs with the back legs. After I had crawled past the jam in the aisle, I fell down and continued to crawl, at that I shouted to all the passengers that they got down on the floor and crawled because there had been an acrid smoke above and it was impossible to breathe... There had been no jam in the nose section... I crawled towards the exit with my eyes shut, slightly opening them not to lose my way. While having been on floor I continued to crawl and tried to maintain breathing with shallow breaths and tried to concentrate myself for not to faint. When I almost crawled to the exit,

somebody picked me up from the left side and somebody grabbed my right shoulder, and, dragging me along the corridor, pushed me out on the right escape slide of the airplane... when I moved away from the aircraft to a safe distance, the passenger of this flight [Name Surname] came up to me after a while, who told me that he with the female flight attendant[87]*had pulled me out along the corridor to the exit and pushed me out to the slide, and further that he helped her to save some more passengers. [Name Surname] told me as well that no one managed to get out the airplane after me».*

As evidenced by the male passenger, having occupied the seats 12A and 12C with his spouse and having been the last to leave the aircraft:

«When I got up from my seat, due to the strong smoke of the cabin I first bent over and squatted past several rows, after that I lay down on the stomach and crawled towards the front emergency exit out of the airplane. It took me not more than one minute and as I can remember within this time I took three breaths, with that the last one I made through a carpeting, lying on the floor, after that I reached the emergency exit… I was leaving the airplane without my belongings. When my spouse got up from her seat, she took the handbag with her and my jacket out of the opened overhead bin, she covered the face with it...». At the emergency exit this passenger saw the female flight attendant and a man, wearing a uniform, whom he identified as a pilot. When the flight attendant went down the escape slide, the passenger stayed at the emergency exit with the pilot and assisted him in evacuating the passengers: *«…when I reached the front emergency exit, out of the smoke-filled cabin I saw the arms of a woman, having lied on the floor. We together with the airplane PIC*[88] *pulled the woman out and threw her down the slide, after which almost immediately we saw the arms of a man lying on the floor of the airplane*[89]*. Together with the PIC we pulled him out as well and threw him down the slide. After that the open flame spouted out from inside the cabin. I suggested the PIC that we should take the full face respirators to step inside the cabin. The PIC came to the cockpit, pulled at the door, which was locked, after that he took out a flashlight from the box to the left of the cockpit door. He shone a flashlight inside the cabin, where nothing could have been seen because of the smoke and fire, after which he said: «That's it, we're leaving.» Once he said it, I left the airplane cabin by the slide on my own ... I was the last of the passengers who had been able to evacuate. After me it had been only the PIC of the aircraft, who remained in the airplane cabin».*

[87] With the F/O actually.
[88] As per the interviews of the flight crewmembers, most probably it had been the F/O.
[89] The above mentioned seat 18A passenger, presumably.

1.18.18 On the serious air incident to the RRJ-95LR-100 aircraft MSN 95032 (tail number 97006)

On July 12, 2018 at the performance of the touch and go maneuvers (these involve landing and taking off again without coming to a full stop) in the progress of the test flight at one of the landings a very hard touchdown had been recorded with the weight of 40900 kg and the recorded acceleration of 4.18G. The landing was performed at the FBWCS operation in NORMAL MODE with the A/P and A/T disengaged. The hard touchdown was caused by the flight crew's failure to monitor the parameters of descent (the flight path angle, namely), which prevented the arrest of the vertical speed down to the required values at flare.

The result had been the shearing of the right MLG leg attachment A fuse pins with the other landing gear structural elements and fuel tanks having remained intact. The aircraft ran on a RWY for more than 16 sec. and took off. After liftoff there was an attempted landing gear retraction, which resulted in the right MLG leg jam in a half retracted position due to the leg turn around its axis, as it had been locked at the attachment B only. The flight had been proceeded until the final reserve fuel and had been successfully completed with the emergency landing on a maintained RWY. At that the structural damage had been the result of the landing on the MLG leg, having been in an intermediate, half retracted position with the unlocked braces. As into this emergency landing there had been no exceedance of the acceleration and vertical speed, consequently the loads remained within the operating limits, the landing gear crossarm had not been disintegrated and remained at the attachment B, there had been damage neither to the landing gear beam, nor to the hinge bracket. Thereby there had been no application of loads, exceeding the ultimate ones, on the wing structural elements and no damage that would result in the fuel leakage.

1.18.19 On the post-accident activities, held by the aircraft designer in association with EASA

In order to demonstrate to EASA experts the handling qualities of the RRJ-95 aircraft, at the facilities of SuperJet International (Venice, Italy) over September 30 – October 4, 2019 two sessions had been held of 6 hours total time at the Level D FFS, which has been issued the EASA certificate and is used for the transition and recurrent training of the RRJ-95B[90] aircraft flight crew personnel together with the performance of two test flights aboard the MSN 95120 aircraft of 3 hrs 25 min. total time. As the outcome of the activities, the respective Minutes of Meeting had been drawn up.

[90] As explained by the aircraft designer representatives the software (engineering model) of this FFS does not substantially differ from this, installed at Aeroflot, PJSC.

In the progress of the session the simulation had been carried out at the FFS under different combinations of weight and CG, including the simulation of the conditions of the RA-89098 flight that ended up with the accident. The particular attention had been given to the presence of the tendency to the APC (PIO). The FFS activities had resulted in the determination of the following:

– there is no tendency to the onset of the APC (PIO) at the FBWCS operation in NORMAL MODE and DIRECT MODE;

– the damping in pitch in noticeably less in DIRECT MODE against the NORMAL MODE. However it is easily offset by one or two additional sidestick inputs;

– the gain of the pilot's workload at the FBWCS DIRECT MODE, provided the aircraft is balanced (appropriately trimmed), is consistent with the MINOR failure condition to all the flight stages, except for the NPA and go-around, where the workload is assessed as MAJOR failure condition due to the degraded flight control automation against NORMAL MODE[91];

– at the stage of flare, on condition the aircraft is balanced (appropriately trimmed), there are no substantial differences in the piloting technique against NORMAL MODE. If the airplane is out of trim by an amount, corresponding to approximately 1° of the stabilizer deflection, the safe performance of landing is still possible.

The flights had been performed aboard the MSN 95120 aircraft. In the first flight the aircraft handling qualities in the FBWCS NORMAL MODE had been evaluated, in the second flight – these had been done in DIRECT MODE. The flights had been performed in series under similar conditions on the same runway. The flights had resulted in concluding the following:

– in both FBWCS operational modes the airplane flight dynamics is replayed well at the FFS;

– piloting the airplane is slightly easier than the FFS, as the aircraft is felt slightly more stable and having better damping;

– the airplane had been easy to trim in manual mode into all the standard maneuvers (acceleration-deceleration, the turns of a different bank, the approach). The maintaining of altitude is of no difficulty for a medium-skilled pilot;

– at the performance of the dynamic (the sidestick input of the 80% of travel) maneuvers, such as «the pitch hold», the minor residual oscillations are observed in DIRECT MODE that are easily offset by one or two slight 30% of travel at most) additional sidestick inputs;

[91] Formally, as per the Consolidated List of the RRJ-95B Aircraft Emergencies # RRJ0000-RP-121-1273, coordinated and approved on January 27, 2011, the FBWCS reversion to DIRECT MODE is classified as the MAJOR FAILURE CONDITION for all the flight stages.

– provided that the airplane is balanced (appropriately trimmed), the piloting technique at flare does not substantially differ as by the FBWCS operational modes in terms of the magnitude, number and frequency of the sidestick deflection.

It had been noted as well that the FCOM F/CTL DIRECT MODE procedure description requires no amendment and integrates all the necessary guidance for the safe completion of the flight.

The analysis of the flight data records (Fig. 124 and Fig. 125) to the flight, having been performed in DIRECT MODE, accomplished by the investigation team revealed the following:

- into the steady-state flight the crew had constantly applying aircraft manual trim in pitch. The maintenance of the flight parameters on the trimmed airplane had not been anyhow challenging;
- to maintain the constant roll into turns against the inoperative turn coordination function the crew had generally applied the method, involving the sidestick retaining deflected. In certain cases the crew further applied pedals;
- prior to the initiation of the glideslope descent the crew configured the airplane for landing. At the stabilizer setting of 2.7° to nose-up, while decreasing the airspeed down to the target landing speed of 152 kt, the maintenance of the flight in pitch had been ensured with the sidestick input to nose-up;
- after the initiation of the glideslope descent the flight parameters (the IAS, flight path angle) had been stabilized and the crew accomplished the aircraft trim by further resetting the stabilizer up to 4.4° to nose-up;
- once the aircraft trim and selection of the engine power rating completed, the maintenance of the descent glidepath from the altitude of about 1500 ft had been enabled with the short-term slight sidestick inputs, most of the time the sidestick had been positioned neutral. The engine power rating had not been changed. The deviations off the glideslope equisignal zone had not exceeded 0.4 dot, as to the IAS they remained within 5 kt. The flight had been fully stabilized;
- the RWY threshold was flown over at the true altitude of 51 ft and target approach speed;
- after the engines were set on IDLE and the flare was initiated the sidestick had been repositioning to nose-up by not more than 8.2°. The sidestick had never been returning to neutral and deflecting to nose-down;

- the flare had resulted in the established aircraft pitch of 5-6° and the arrest of the vertical speed and IAS;
- the landing occurred with the pitch of 5° approximately to nose-up at the IAS of 142 kt with the concurrent WOW to both MLG legs. The maximum recorded acceleration amounted to 1.16G;
- in under a second after landing the speedbrakes had been manually deployed, thus preventing consecutive bounce off the RWY. The TR had not been applied;
- prior to the onset of the steady WOW to the MLG legs there had been no sidestick input beyond neutral to nose-down;
- the NLG had been lowered smoothly with no consecutive separations;
- into the landing roll the crew had been maintaining the sidestick forward position by a half-travel approximately.

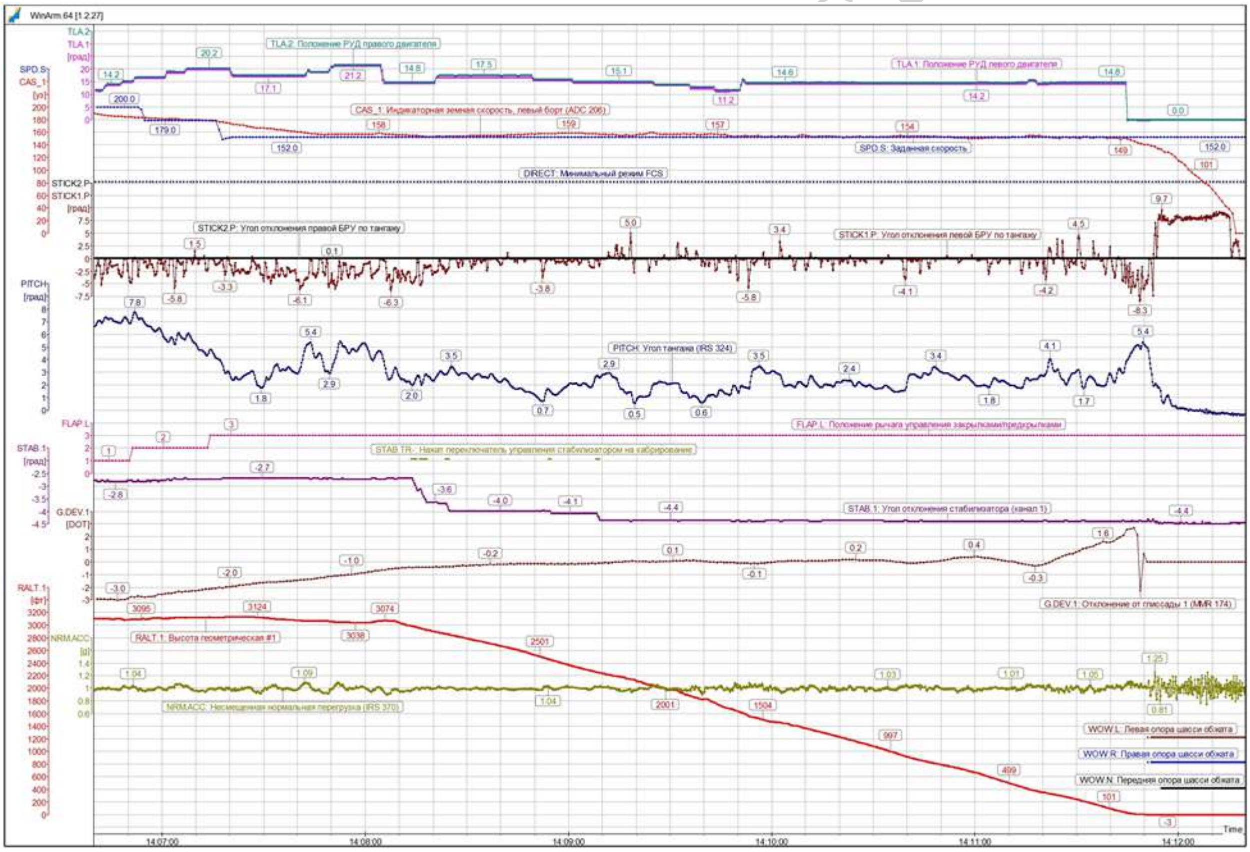


Fig. 124. The flight data at the Venice airport approach on October 2, 2019

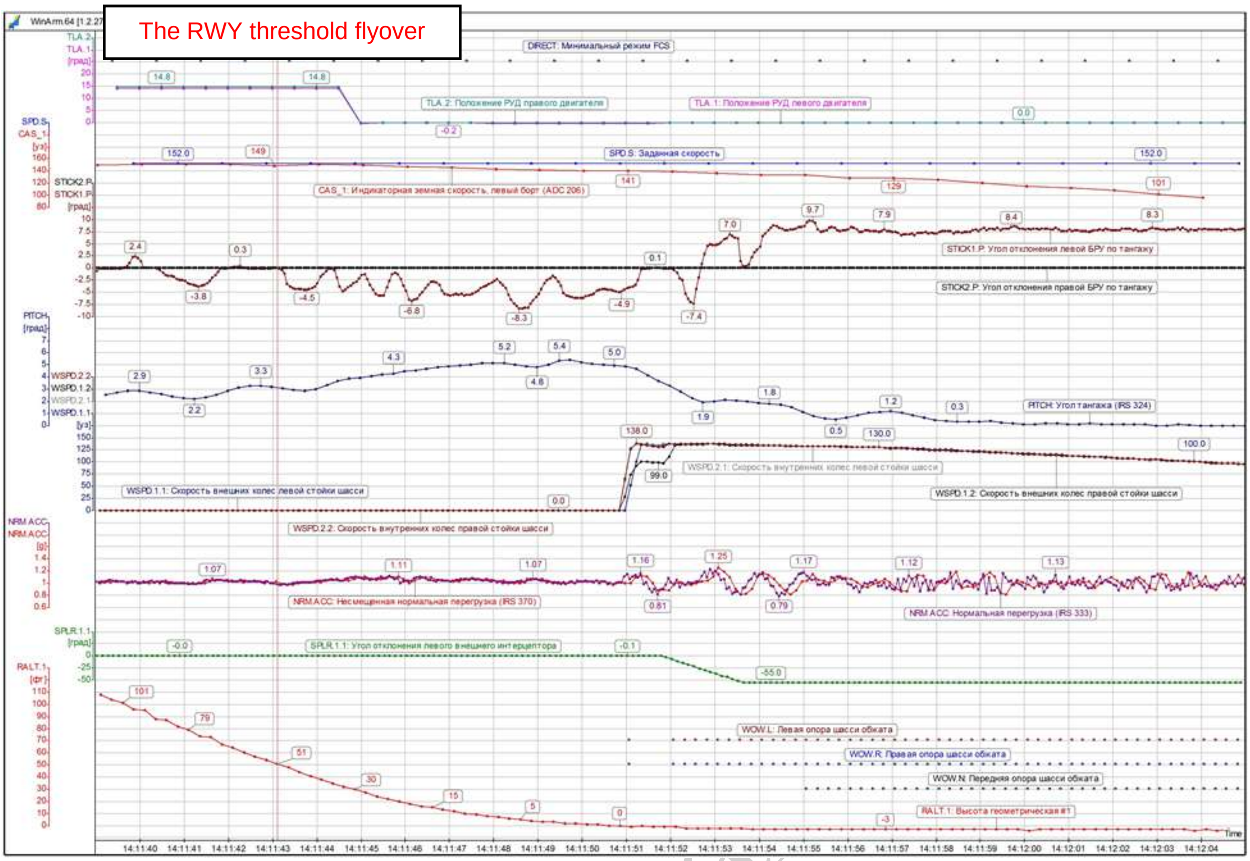


Fig. 125. The flight data into flare, landing and landing roll at the Venice airport on October 2, 2019

1.18.20 On the evacuation aids (escape slides) of the RRJ-95 family aircraft

The passenger cabin is equipped with the evacuation assisting aids (the escape slides) that enable the evacuation of the passengers and crewmembers through the front and rear emergency exits at the emergency landing of the aircraft with landing gear down, up and at the collapse of one or more landing gear legs. Each slide is a gas-filled shell, packed in the container. The container with the slide is attached to the door frame. Inside the door frame the mechanism is allocated of the slide connection to the cabin floor. At the emergency opening of the door the slide is automatically erected within 10 sec. at most. The works on the scheduled operational check of the escape slides and their maintenance is introduced in the RRJ-95 aircraft operational and technical documentation.

The escape slides compliance to the regulations requirements had been confirmed at the performed certification tests that included the assessment of performance and the engagement of the emergency exit door/escape slide system, as well as the demonstration of the passengers and crewmembers evacuation on ground. The performed certification works resulted in the issuance of The Summary Report on the Compliance of the RRJ-95B Aircraft Emergency and Rescue Equipment With the Certification Basis # RRJ0000-RP-012-1371.

1.18.21 The description of the MLG legs design

By design the MLG leg is a two-brace[92] assembly and incorporates the components as follows (Fig. 126):

– MLG leg shock absorber (1);

– drag brace (2) and side brace (3);

– retraction/extension actuating cylinder (4);

– uplock (5).

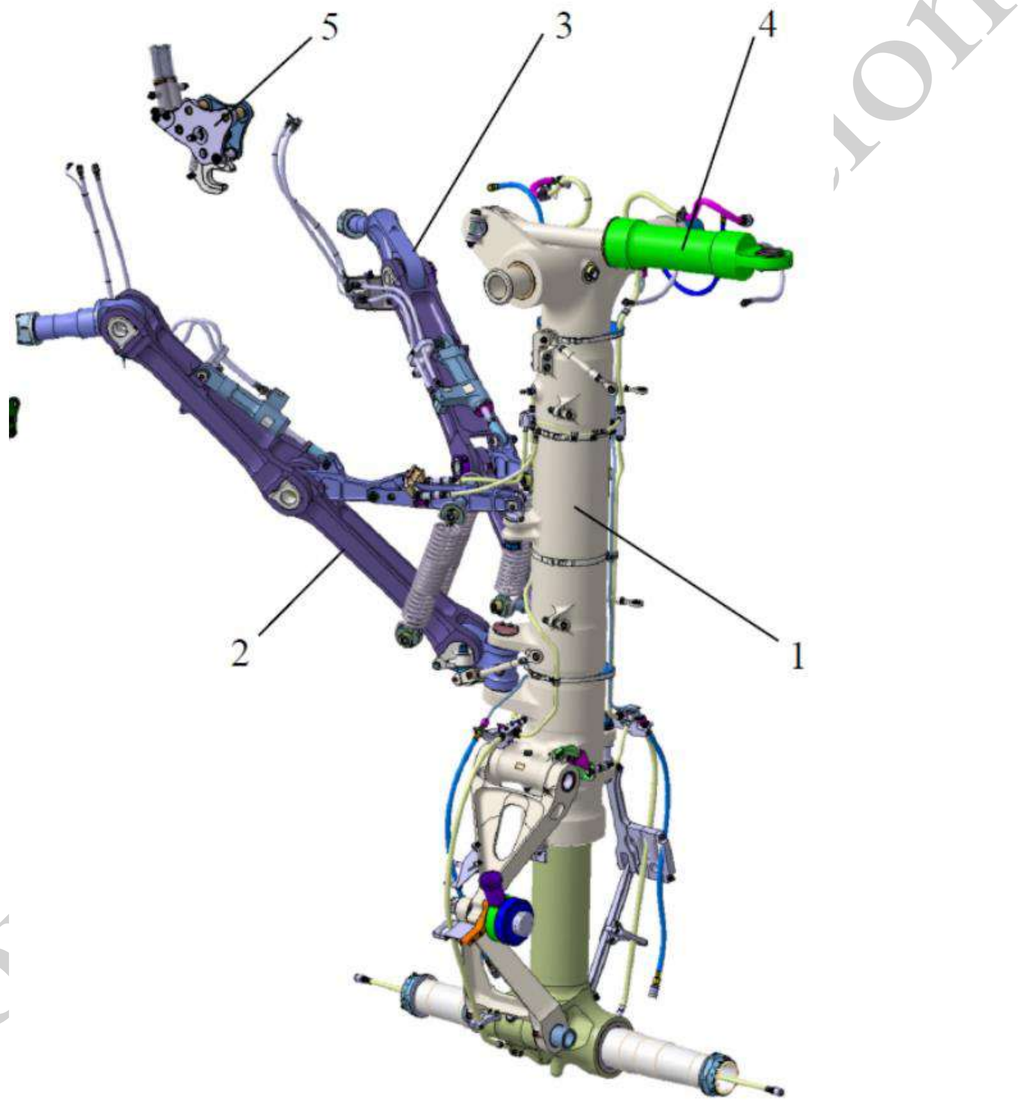


Fig. 126. The MLG leg

The MLG leg is attached to the airframe structure in the following points (Fig. 127):

– the crossarm FWD attachment A is attached to the wing box rear spar;

– the crossarm aft attachment B is attached to the LG crossbeam;

– the attachment point of the drag brace is on the wing box rear spar;

[92] The Boeing 767, 777, 787, Airbus A350 and some other aircraft integrate the MLG leg of the similar design.

– the attachment point of the side brace is on the LG crossbeam.

The retraction/extension actuating cylinder is attached to the spar web. The LG crossbeam at one end is attached to the wing box rear spar and at the other end is to the fuselage. The wing box at the area of the MLG leg attachment is a fuel storage container.

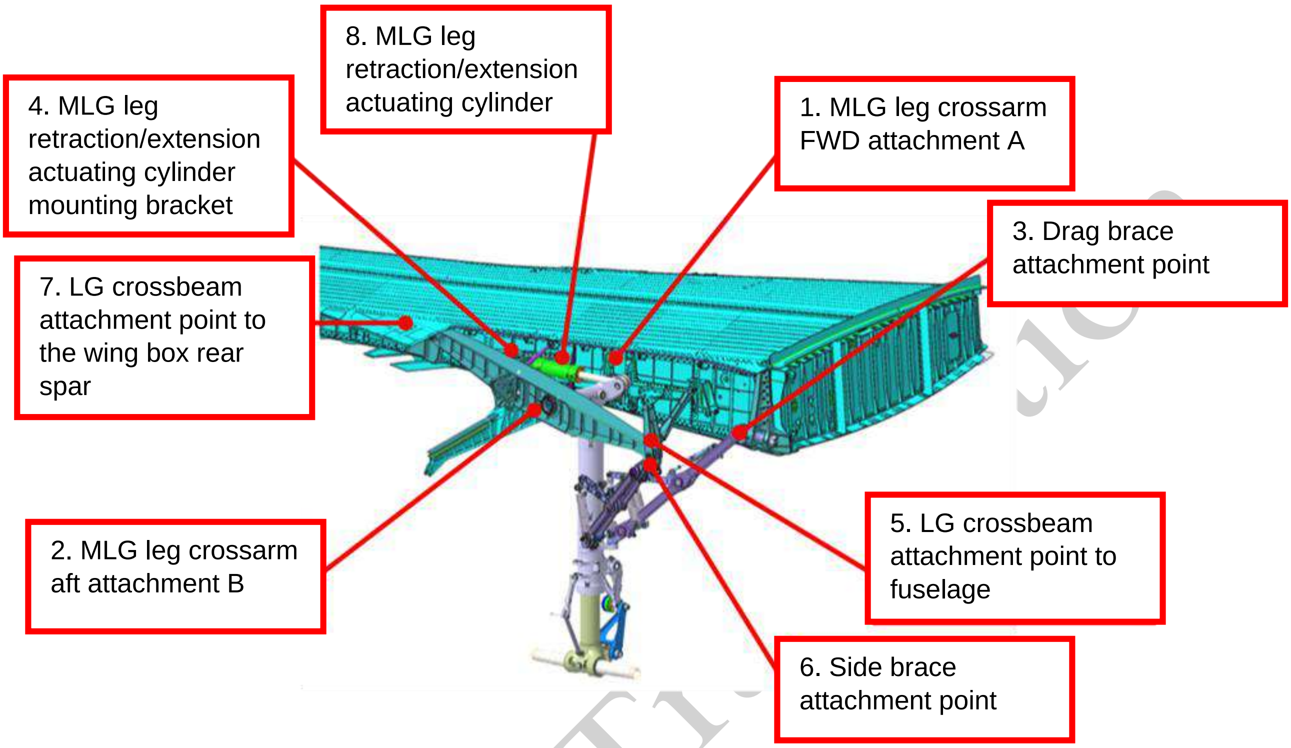


Fig. 127. The attachment of the left MLG to the aircraft airframe

The MLG leg frame features the safe structural destruction at the one-time application of the load, exceeding the ultimate one (at the occurrence of the excessively hard landing, the landing with the NLG coming first at the pitch rate large component, etc.)[93].

The crossarm FWD attachment A design incorporates the «weak links» – the fuse pins (Fig. 128), the sections of which are selected in such a way that at the exceedance of the ultimate loads, applied on the leg, their (the fuse pins) destruction occurs first of all, enabling the safe separation of the leg off the rear spar. This feature is by nature irreversible. The design of the FWD attachment A incorporates four fuse pins to each leg. As for the manufacture the fuse pins are attributed as the critical PSE: the blanks are subject to the special incoming inspection for the custom-made part configuration, whereas the parts themselves are subject to the periodical sampling inspections[94].

[93] This feature has been introduced to ensure compliance with the AR-25 item 25.721(a), (2), (в), (c) and is attributed as a design precaution on preventing the spillage of enough fuel from any fuel system in the fuselage to constitute a fire hazard in the event of the MLG legs destruction.

[94] Into the airplane certification the analysis of the potential fuel spillage out of the wing box at the MLG legs destruction is carried out by the computational methods, by simulating the process of the MLG leg destruction notably at the exceedance of the ultimate loads application on the LG legs. Based on the computation the integrity and structural requirements are determined to the fuse pins into the LG attachment fittings.

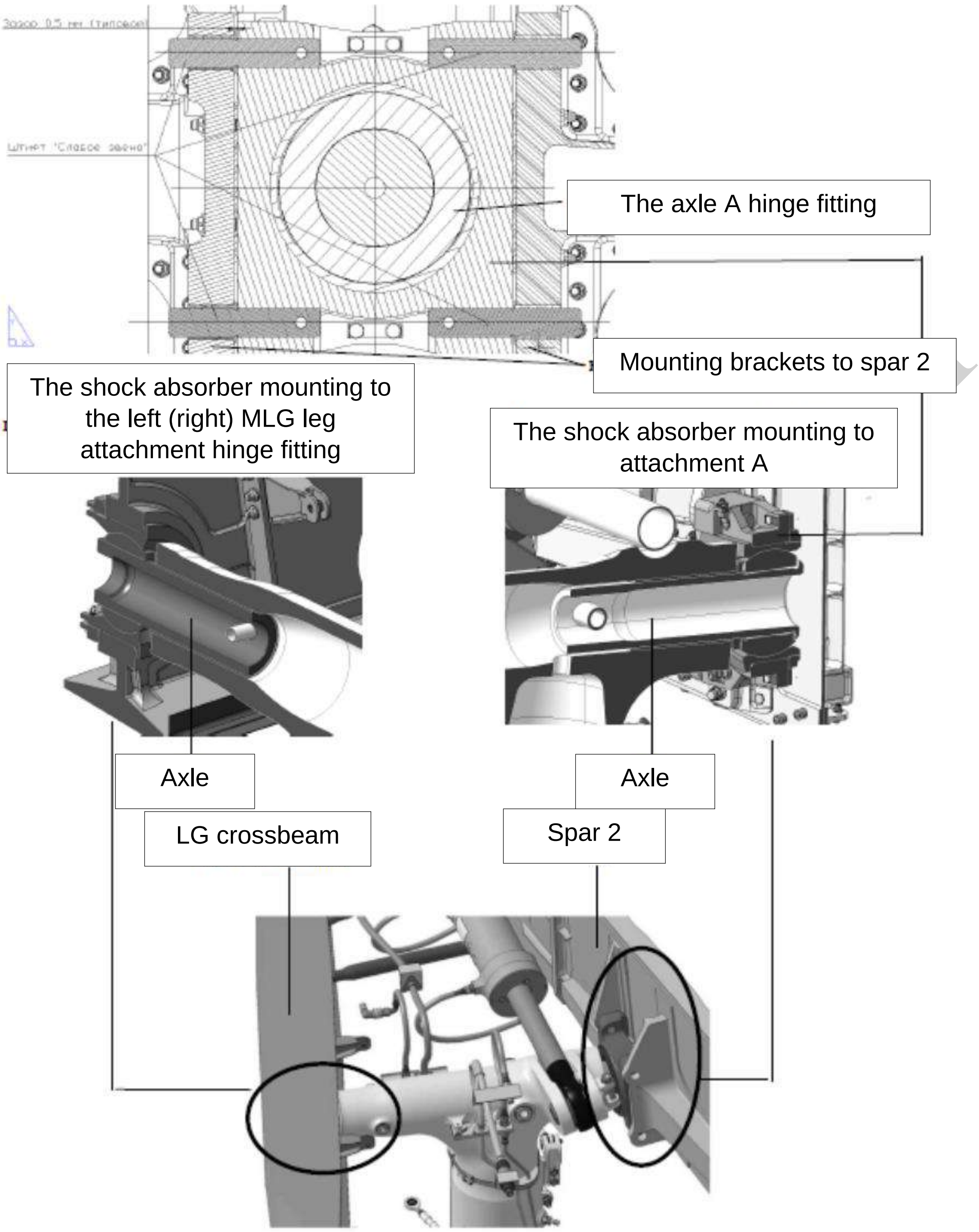


Fig. 128. The crossarm attachment points to the A rear spar and to the LG crossbeam

The design of the node of the drag brace upper cardan pin by the pivot to the spar incorporates the fuse element as well (the «weak link») in the form of the customized weakening of the trunnion pin into the movable joint (Fig. 129) that is to disintegrate at the exceedance of the ultimate load, which ensures the safe separation of the brace off the spar.

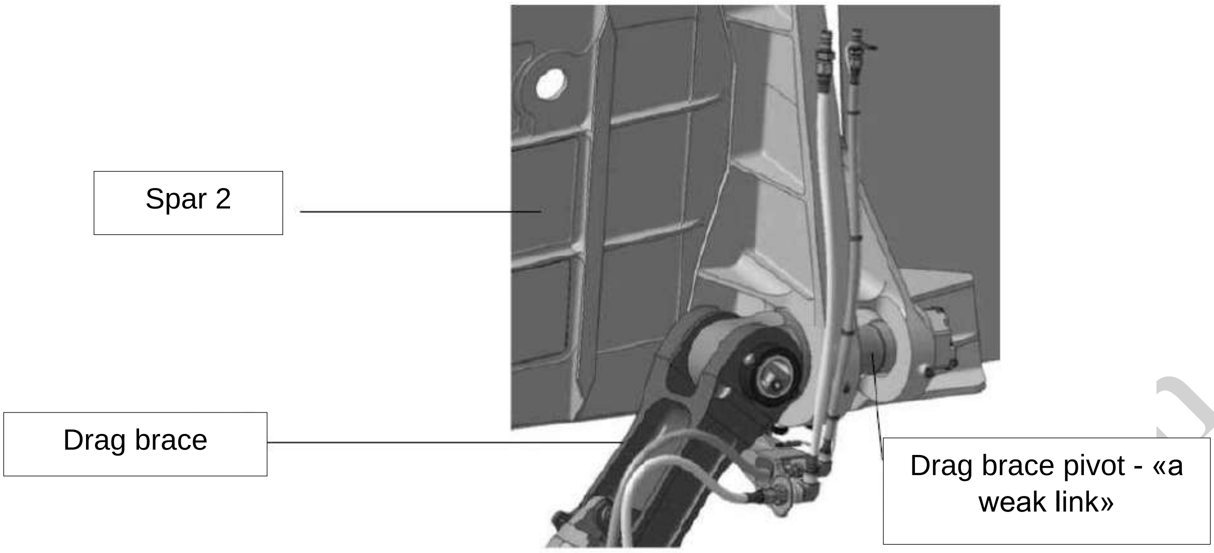


Fig. 129. The drag brace attachment point to the rear spar

1.18.22 On the type certification of the RRJ-95 aircraft

The RRJ-95 aircraft has the Type Certificates, issued by IAC AR, EASA (the validation of the Type Certificate, issued by IAC AR) and FATA.

The dates of the application filing:

1) to IAC AR

By the letter with ref. # 173 of April 15, 2004 the Application for the RRJ-95 aircraft Type Certificate of April 8, 2004 had been filed. By the letter with ref. # 6.21-629 of April 28, 2004, the IAC AR had notified of the acceptance of the Application to be processed and of the appointment of the head of the expert group.

Compliant to the IAC Aviation Regulations item 3.2.4, Part 21 «Aircraft Certification Procedures» of the year 1999 (hereinafter referred to as AR-21) the application validity is 5 years. The extension of the Application was not allowed by the AR-21 edition of the year 1999, for which reason by the letter with ref. # 2794/354 of April 24, 2009 SCAC, CJSC had submitted an updated Application for the Type Certificate.

By the letter with ref. # 06.96-843 of May 14, 2009 the IAC AR notified of the acceptance of the updated Application to be processed. The letter read inter alia: *«Due to no change in the current regulatory certification requirements (AR-25) since the filing of the original Application for the certification of the RRJ aircraft the earlier declared Certification Basis (CB) is to be maintained subject to the amendments to the CB, approved by IAC AR»*.

On January 28, 2011 the Type Certificate # CT 322-RRJ-95 had been issued by IAC AR.

2) to EASA

By the letter with ref. # 6.58 of July 22, 2004 the IAC AR submitted the SCAC, CJSC Application for the RRJ-95 aircraft Type Certificate to EASA.

According to EASA Part 21 item 21.15 «Rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organizations», the Application validity is 5 years. The requirements of the EASA Part 21 had allowed for the extension of the Application validity. By the letter with ref. # 4632/354 of July 3, 2009 SCAC, CJSC submitted to IAC AR - to be further forwarded to EASA – the letter, requesting the extension of validity of the Application for the RRJ-95 aircraft Type Certificate validation. By the IAC AR letter with ref. # 06.97-1258 of July 7, 2009 the SCAC, CJSC request on the Application extension, which had been supported as well in the IAC AR position on CRI A-01 «Determination of the Certification Basis» edition 8.

EASA in its feedback position (edition 9) on CRI A-01 «Determination of the Certification Basis» had agreed to the extension of the Application for Type Certificate Validation and offered to apply the «twin-brothers concept» to this validation process, which implies that the date of the applicable amendment to the Airworthiness Standards (Part 25) will be determined by subtracting 5 years from the date of the IAC AR Type Certificate receipt by SCAC, CJSC.

The EASA the RRJ-95 aircraft Type Certificate had been received on February 3, 2012.

3) to FATA

On August 28, 2017 SCAC, CJSC had forwarded the request to FATA on the issuance of the Type Certificate. The request had been appended inter alia with the new (up-to-date) edition of the Certification Basis (# RRJ0000-LS-204-021RU, revision H).

On January 26, 2018 FATA issued the Type Certificate # FATA-01020A. It had been submitted to SCAC, JSC by the FATA letter with ref. # Исх-3521/16 of February 15, 2018.

In line with the above stated the RRJ-95 aircraft is subject to the requirements:

- the AR-25 Amendment 5 as for the IAC AR and FATA certification;
- the CS-25 Amendment 1 + CRI as for the EASA certification.

Within the investigation under discussion the investigation team found it essential to review item 25.721, having been a part of the RRJ-95 aircraft Certification Basis to establish requirements to the effects of the landing gear system exposure to the loads, exceeding the ultimate ones and resulting in its destruction at the aircraft takeoff and landing.

The following presents the substance of this item in the different documents.

AR-25 Amendment 5

25.721. General terms

(a) The main landing gear legs shall be designed so that in the event of their destruction at the application of the loads, exceeding the ultimate ones at takeoff (takeoff run) and at landing (landing roll) (the loads are assumed to act upwards and backwards) the nature of destruction is such to prevent:

(1) as to the aircraft with the passenger seating configuration of 9 seats at most, excluding the pilots' seats, the spillage out of any fuel system in fuselage in the amount, enough to constitute a fire hazard; and

(2) as to the aircraft with the passenger seating configuration of 10 or more seats, excluding the pilots' seats, the spillage out of any fuel system in fuselage in the amount, enough to constitute a fire hazard.

(b) the airplanes with the passenger seating configuration of 10 or more seats, excluding the pilots' seats, shall be designed so that the airplane in a controlled condition would be capable to perform landing on the runway at one or more legs failure to extend; at that it shall be no occurrence of the structural damage as such to cause the fuel leakage in an amount, enough to constitute a fire hazard.

(c) The compliance to the requirements of this para can be demonstrated by the analysis (the estimation, the examination) or by the tests or by a combination of both.

The aircraft Certification Basis # RRJ-95 RRJ0000-LS-204-021/RU revision G (IAC AR) and revision H (FATA)

25.721. General terms

(a) The main landing gear legs shall be designed so that in the event of their destruction at the application of the loads, exceeding the ultimate ones at takeoff (takeoff run) and at landing (landing roll) (the loads are assumed to act upwards and backwards) the nature of destruction is such to prevent:

(1) not applicable

(2) As to the airplanes with the passenger seating configuration of 10 or more seats, excluding the pilots' seats, the spillage out of any segment of the fuel system in fuselage in the amount, enough to constitute a fire hazard.

(b) The airplanes with the passenger seating configuration of 10 or more seats, excluding the pilots' seats, shall be designed so that the airplane in a controlled condition would be capable to perform landing on the runway at one or more legs failure to extend; at that it shall be no occurrence of the structural damage as such to cause the fuel leakage in an amount, enough to constitute a fire hazard.

(c) The compliance to the requirements of this para can be demonstrated by the analysis (the estimation, the examination) or by the tests or by a combination of both.

The EASA Certification Basis, CS-25 Amendment 1

CS 25.721 General

(a) The main landing gear system must be designed so that if it fails due to overloads during take-off and landing (assuming the overloads to act in the upward and aft directions), the failure mode is not likely to cause –

(1) For aeroplanes that have a passenger seating configuration, excluding pilots seats, of nine seats or less, the spillage of enough fuel from any fuel system in the fuselage to constitute a fire hazard; and

(2) For aeroplanes that have a passenger seating configuration, excluding pilots seats, of 10 seats or more, the spillage of enough fuel from any part of the fuel system to constitute a fire hazard.

(b) Each aeroplane that has a passenger seating configuration, excluding pilots seats, of 10 or more must be designed so that with the aeroplane under control it can be landed on a paved runway with any one or more landing gear legs not extended without sustaining a structural component failure that is likely to cause the spillage of enough fuel to constitute a fire hazard.

(c) Compliance to the provisions of this paragraph may be shown by analysis or tests, or both.

The EASA RRJ-95 aircraft Certification Basis had been complemented with CRI C-04 «Emergency Landing Conditions and Landing Gear», integrating the Interpretative Material on the issues of the demonstration of compliance to a number of the Certification Basis items, including item 25.721. The following presents the excerpts out of CRI C-04 in terms of the circumstances of the air accident in question:

In showing compliance to CS … 25.721 …, the following interpretative material is an acceptable interpretation:

1. The aircraft has to be designed to avoid ruptures that could be catastrophic for the safety of the occupants, including ruptures leading to fuel spillage under the following conditions:

…

1.3 Failure of the landing gear under overload, assuming the overload conditions to be any reasonable combination of drag and vertical loads.

2. Consideration should also be given to:

…

2.2 The possible failure of the landing gear under overload conditions including side loads.

…

Landing gear separation. (Compliance to CS 25.721(a) …)

Failure of the landing gear under overload should be considered, assuming the overloads to act in any ***reasonable***[95] *combination of vertical and drag loads, in combination with side loads*

[95] It has been highlighted by the investigation team.

acting both inboard and outboard up to 20% of the vertical load or 20% of the drag load, whichever is greater. It should be shown that at the time of ***separation***[96] *the fuel tank itself is not ruptured at or near the landing gear attachments. The assessment of secondary impacts of the airframe with the ground following landing gear separation is not required. If the subsequent trajectory of a separated landing gear would likely puncture an adjacent fuel tank, design precautions should be taken to minimize the risk of fuel leakage.*

Compliance to the provisions of this paragraph may be shown by analysis or tests, or both.

In response to the corresponding request EASA indicated that it is the *«combination»* noun that the definition (adjective) *«reasonable»* is related to, and not to the magnitude of the potential loads. In other words the aircraft designer at the demonstration of compliance is to determine the reasonable combination of the vertical and longitudinal loads both with and without the additional lateral load, at that the magnitudes of these loads are not governed by the certification documents. Typically the longitudinal and lateral loads are determined as some percentage of the assumed vertical load.

At that the word *«separation»* should be considered precisely as the complete separation of the MLG legs with the destruction of all the attachments, and not as the breakage of one or several attachments, though with the landing gear loss of capability to operate - to absorb and transfer loads. Several conclusions can be made from the EASA explanations:

- the requirements cover the stages of takeoff and landing on the paved runways;
- the available certification documents do not establish requirements to «the reasonableness» of the loads magnitude, under which the LG destruction is evaluated, but only to «the reasonableness» of their combination (the percentage);
- the effect of the «net» («isolated») vertical and horizontal loads is not considered the «reasonable» combination and is not reviewed within the scope of CRI, made out by EASA;
- the CRI deals with the occurrences up to point of the complete separation of the MLG leg (along all the attachments). Only the occurrences are reviewed of the first (one-time) application of the destructive loads in a chosen «reasonable combination». The second and subsequent load applications even though at the first application there was no MLG leg separation along with the aircraft impacts on ground after the complete LG separation are not addressed in CRI.

[96] It has been highlighted by the investigation team.

Item 25.721, stated here above, integrates the requirement on the unacceptability of the fuel spillage out of any part of the fuel system in the amount, *«enough to constitute a fire hazard»* (*«the spillage of enough fuel … to constitute a fire hazard»*).

At the time of the RRJ-95 aircraft certification IAC AR had not have any documents that would have specified «the sufficiency» of the fuel spillage to constitute a fire threat (hazard). There had been no explanations of the kind in the EASA documents either.

At the time of the RRJ-95 aircraft certification by FATA this competent authority had not have any amendments in its Certification Basis, as far as item 25.721 is concerned, against the IAC AR Certification Basis.

For the first time the concept of «sufficiency» had been specified in Book 2 «Acceptable Means of Compliance (AMC)» Part 25 of the European Union Aviation Safety Agency (EASA), in AMC 25.963 (e) «Fuel tank protection». This concept appeared in Amendment 14, which had been enacted by the European Commission on December 20, 2013:

AMC 25.963(e) Fuel Tank Protection

3. IMPACT RESISTANCE.

a. …

A hazardous fuel leak results if debris impact to a fuel tank surface (or resulting pressure wave) causes:

(i) a running leak,

(ii) a dripping leak, or

(iii) a leak that, 15 minutes after wiping dry, results in a wetted aeroplane surface exceeding 15.2 cm (6 in) in length or diameter.

The leak should be evaluated under maximum fuel pressure (1g on ground with full fuel volume, and also considering any applicable fuel tank pressurization).

As a part of the certification activities on the demonstration of the aircraft compliance to Certification Basis item 25.721 the engineering simulation[97] had been carried out of the MLG legs destruction under the application of the loads, exceeding the ultimate ones. The results are stated in the documents as follows:

- The research report RRJ0000-RP-100-1369 Rev. A. «The computational studies of the RRJ-95 airplane gear-up landing» Sarov Engineering Center. 2010 (hereinafter referred to as Report [2]);

[97]The compliance with item 25.721 had been confirmed by the engineering simulation. There had been no tests in situ carried out, which is acceptable.

- The research report RRJ0000-RP-100-1751 Rev. A «The computational studies as a part of drawing up of the certification documentation to the RRJ-95B airplane for EASA» Sarov Engineering Center. 2011 (hereinafter referred to as Report [7]);
- The RRJ-95B airplane. The analysis of the effect of sequences of the MLG legs destruction on the occurrence of the spillages out of the fuel system, enough to constitute a fire hazard. The report RRJ0000-RP-100-1827 Rev. A. 2011 (hereinafter referred to as Report [10]);
- The RRJ-95B airplane. The analysis of the effect of sequences of the MLG legs destruction on the occurrence of the spillages out of the fuel system, enough to constitute a fire hazard. The report RRJ0000-RP-100-1324. 2010 (hereinafter referred to as Report [11]).

In the Report [2] the design cases as follows had been addressed:

1: the exceedance of the maximum vertical load at the vertical speed of landing of 3 m/sec;

2: the exceedance of the maximum longitudinal load at the longitudinal speed of 50 m/sec.

The results of the performed works on the design cases of the exceedance of the maximum vertical load #1 [2] and maximum vertical load # 2 [2] had been stated in the Report [11].

The design cases, addressed in the Report [11], as well as the applied method for establishing compliance had been accepted by the IAC AR at the initial certification and by FATA at the issuance of the FATA Type Certificate.

On the basis of the EASA CRI C-04, the aircraft designer had carried out the additional analysis of the leg separation under the effect of combination of the vertical, longitudinal and lateral loads, vectored both towards and from the fuselage, which had been addressed in the Report [7], attributed as the design cases # 2 and # 3. The Report [7] integrates as well the cases of the MLG leg destruction, affected by the combination of the vertical and longitudinal loads # 1 and the exceedance of the maximum vertical load # 4.

In the Report [7] the design cases as follows are reviewed:

1: the combination of the vertical and longitudinal loads (it had been assumed that the vertical load is applied to the wheel axle, combined with the longitudinal load of 50 % of the vertical one, the amplitude of which is infinitely increasing to the point of the complete destruction of the attachment fittings);

2: the combination of the vertical, longitudinal and lateral loads, vectored inboard. The lateral load amounts to 20 % of the vertical one or 20 % of the longitudinal load, whichever is larger;

3: the combination of vertical, longitudinal and lateral loads, vectored outboard. The lateral load accounts for 20 % of the vertical one or 20 % of the longitudinal one, whichever is larger;

4: the exceedance of the maximum vertical load at the vertical speed of landing of 3 m/sec.

The results of the analysis of the design cases of the MLG leg destruction under the effect of the combination of the vertical and longitudinal loads # 1 [7], as well as the combination of the vertical, longitudinal and lateral loads, vectored both towards # 2 [7], and from the fuselage # 3 [7], had been addressed in Report [10].

In the Report [10] the design cases as follows are reviewed:

1: the combination of the vertical and longitudinal loads (it had been assumed that the vertical load is applied to the wheel axle, combined with the longitudinal load of 50 % of the vertical one, the amplitude of which is infinitely increasing to the point of the complete destruction of the attachment fittings);

2: the combination of the vertical, longitudinal and lateral loads, vectored inboard (towards the fuselage). The lateral load accounts for 20 % of the vertical one;

3: the combination of the vertical, longitudinal and lateral loads, vectored outboard (from the fuselage). The lateral load amounts for 20 % of the vertical one.

Through the Report [10], reviewed and approved by EASA at the validation of the IAC AR Type Certificate, the compliance to the CRI C-04 requirements had been established and confirmed.

At the comparison of the design cases one can note that to all the cases, as per the performed simulation, the hinge attachment A destruction occurs first of all with no significant damage to the rear spar web (the damage is meant, affecting the load-bearing capacity), but for the short cracking at the attachment fittings.

From the presented it is evident that different certification authorities had taken different design cases for consideration.

Given the circumstances of the air accident under discussion the case of the exceedance of the vertical load # 1 [2] and # 4 [7] is the most similar one. This case had been submitted for review to the IAC AR and FATA only. It had not been submitted to EASA for consideration.

By the simulation it had been determined that as for this design case the sequence[98] of the MLG leg elements destruction had been the following:

– t=9 msec – the leg crossarm FWD attachment A fuse pins («weak links») destruction;

[98] Section 1.18.21 of the Report reads the description of the LG design.

– t=52 msec – the destruction of the LG crossbeam mounting bracket attachment elements to the wing box rear spar;

– t=61 msec – the destruction of the LG crossbeam lug attachment elements to the fuselage;

– t=69 msec – the destruction of the leg crossarm aft attachment B elements to the LG crossbeam;

– t=74 msec – the destruction of the leg retraction/extension actuating cylinder;

– t=79 msec – the destruction of the drag brace lock attachment elements to the leg.

Fig. 130 shows the graph representation of the dependence of the force, applied on the leg, against the time at the engineering simulation.

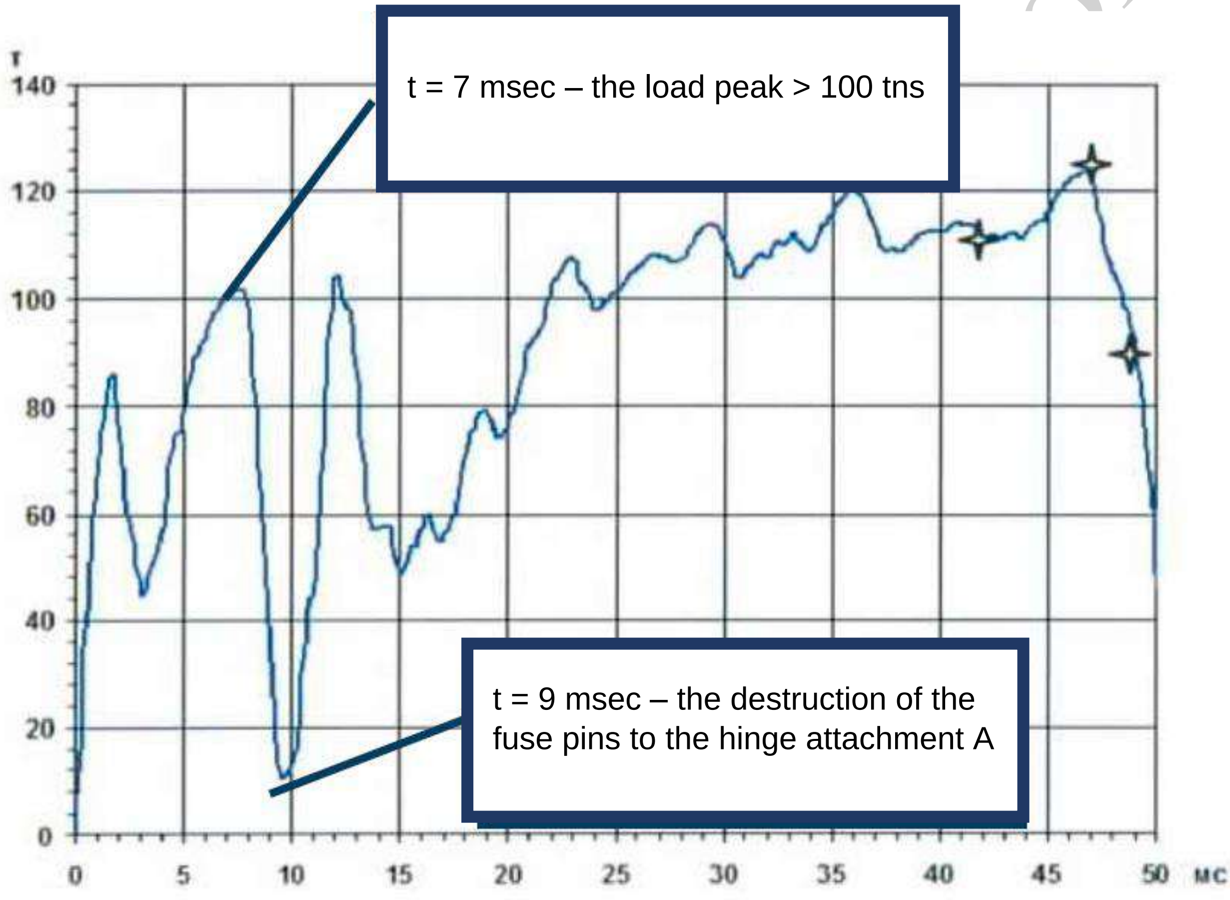


Fig. 130. The force on the leg vs time dependence at the simulation of the leg separation off the airplane under vertical load

1.18.23 On the air accident to the Boeing 777-236ER G-YMMM aircraft at London Heathrow airport (Great Britain) on January 17, 2008

At the approach to London Heathrow airport, Great Britain, there occurred the aircraft landing short of the runway (the undershoot event). All the information on the circumstances and causes of this air accident is given in the AAIB UK Final Report by the link: https://assets.publishing.service.gov.uk/media/5422f3dbe5274a1314000495/1-2010_G-YMMM.pdf

At the first touchdown into soil with the vertical speed of 25 ft/s (7.6 m/sec) both MLG legs had been partially separated. Into another touchdown both of them had no longer been capable to operate as per design (bear and transfer the landing loads) and there occurred the impact with ground by the engine nacelles and NLG that had collapsed in a sequence.

The Boeing 777 aircraft integrates the LG of the two-brace design (Fig. 131), similar to the mounted on the RRJ-95B (see Section 1.18.21 of the Report). To enable «safe» destruction a set of «weak links» (fuse pins) had been introduced in the LG structure.

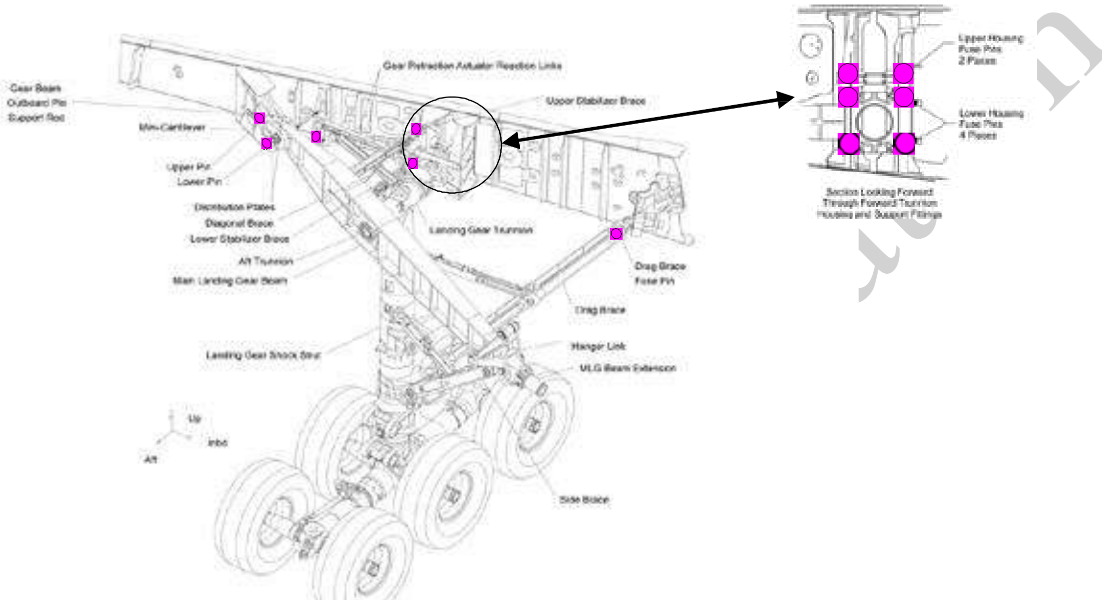


Fig. 131. The MLG legs design to the Boeing 777 aircraft (the «weak links» are indicated with color)

After first contact with ground the partially separated MLG legs proceeded their movement attached to the airplane. The further movement of the left MLG leg did not cause the damage of the fuel tanks structure. By contrast, the movement of the right MLG leg led to its separation at the drag brace attachment with the destruction of the wing rear spar and center fuel tank (Fig. 132 and Fig. 133). The separation occurred under the load, vectored «backwards».

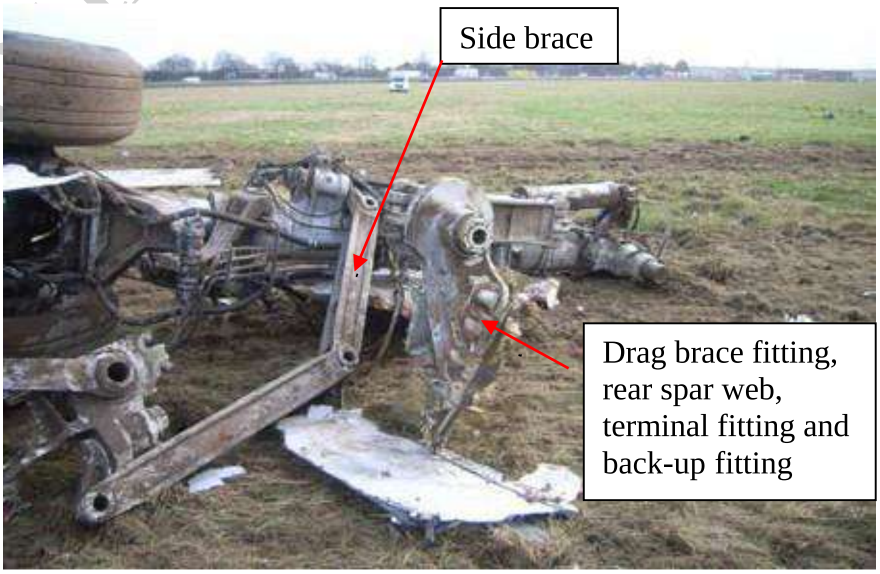


Fig. 132. The post-accident condition of the elements to the right MLG leg and the right wing panel rear spar

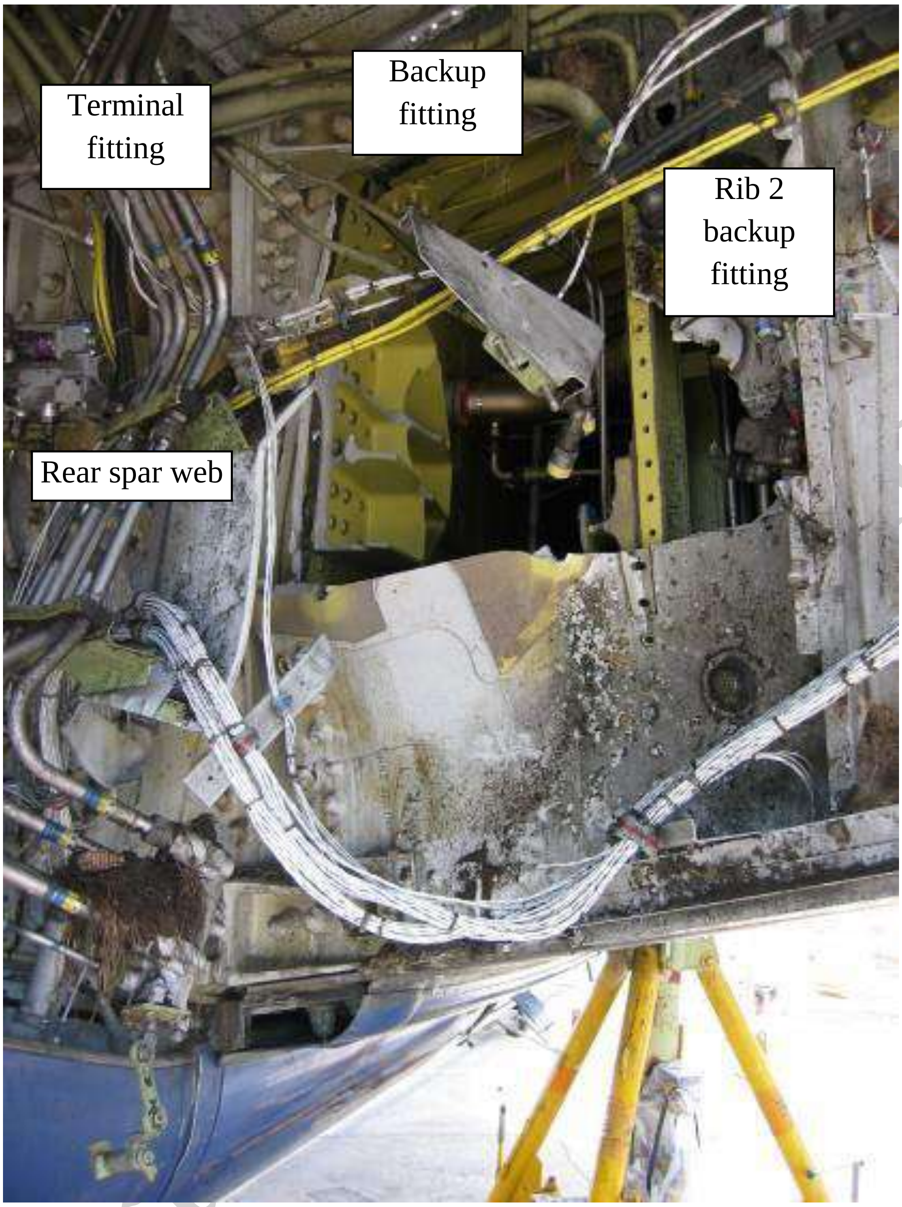


Fig. 133. The exterior of the destruction of the right wing panel rear spar and fuel tank at the MLG leg drag brace attachment

In the progress of the examination it had been determined that the touchdown into a relatively soft soil had contributed to the «non-normal» destruction of the right MLG leg, whereas at the certification of compliance to item 25.721 it had been assumed that the landing is performed on the RWY hard artificial surface.

The investigation outcome had been the issuance of two safety recommendations by AAIB UK, related to the MLG legs and their certification. One of them (2009-095[99]) had been aimed at the amendment of the airworthiness standards, which would cover a larger number of the potential occurrences, involving the LG destruction, inter alia, the event of the landing into «soft ground». The other one (2009-094) had been addressed to the aircraft designer and covered the modification

[99] The sequence number in the AAIB UK reporting system.

of the LG design: *«apply the modified design of the B777-200LR main landing gear drag brace, or an equivalent measure, to prevent fuel tank rupture, on future Boeing 777 models and continuing production of existing models of the type».* According to the information, submitted by AAIB UK, this safety recommendation had been closed with the Rejected – Closed status, that is to say the aircraft designer had not accepted this recommendation for implementation. In the view of the designer, the implementation of this recommendation would not result in a significant increase in aviation safety of the current Boeing 777 fleet. Still the designer specified that it would review the potential of improving the design of the MLG leg drag brace and its attachment point to the B777-200LR aircraft or the equivalent measures on future B777 models «as a product improvement».

1.18.24 On the passenger cabin interior, cabin windows and the fuselage heat and sound insulation

Requested by the investigation team the aircraft designer had drawn up a number of the technical reports.

The technical report RRJ0000-RP-052-5625 Rev. A «On the RRJ-95B/LR airplane passenger cabin in terms of the interior compliance to the aviation regulations requirements on the fire behavior, the passengers and crewmembers' emergency evacuation» reads the data on the aircraft interior, the applicable requirements of the aviation regulations in terms of the fire behavior and the accomplished certification activities on the demonstration of compliance to these requirements. The accomplished amount of tests in terms of proof of compliance to the requirements of the standards for flammability, fire behavior, heat and smoke emission had been subject to analysis. The compliance of the interior with the requirements of aviation regulations as for the emergency evacuation of passengers and crewmembers had been confirmed as well by a real demonstration of emergency evacuation at the certification tests. Based on the outcome of the certification activities, the compliance of the passenger cabin equipment with all applicable requirements of the standards had been shown, the certification documents had been drawn up and approved by the aviation authorities.

The technical report RRJ0000-RE-006-2481 «On the RRJ-95 airplane cabin windows in terms of the compliance of the cabin windows glazing material with the requirements of the aviation regulations on the fire behavior» integrates the analysis with the description of the requirements, applied design concepts (the cabin windows material among them) and the method of the demonstration of compliance. The information is given on the compliance of the passenger cabin windows design with the applicable requirements of the standards in terms of the fire behavior of the glazing material and the analysis of confirmation of compliance to these requirements had been carried out.

In the technical report RRJ0000-RP-023-5707 «On the design and certification of heat and sound insulation of the fuselage to the investigation of the air accident of May 5, 2019» the applied design concepts and method of demonstrating the compliance of fire protection equipment (including heat and sound insulation materials in use) had been subject to analysis, the data are stated on the heat and sound insulation of the RRJ-95 aircraft, its compliance to applicable requirements of the standards and demonstration of compliance to these requirements. The analysis had been made of confirming compliance to the requirements of the standards in terms of flammability and flame propagation according to the tests of materials and structures of thermal and sound insulation according to approved methods. According to the test results, the compliance of the heat and sound insulation materials in use in the structure with the requirements of the standards in terms of flammability and flame propagation had been demonstrated.

At that the current airworthiness standards determine the requirements to the structural elements in question exclusively at the potential onset and propagation of the «internal» fire. There are no requirements, concerning the «external» fire. In particular, there are no requirements on the minimum time of the cabin windows «burnout» in the «external fire» environment. The relevant research had been conducted neither by the cabin windows designer nor by the aircraft designer.

Note: *According to BEA[100], the material used for the cabin windows has to meet, among others, flammability and mechanical resistance requirements. And there is no fireproofness requirement in current certification specifications.*

The material used for cabin windows on this aircraft, which is also commonly used on other commercial aircraft types, is most likely the better compromise between weight and mechanical resistance, while meeting flammability requirements. But, it has intrinsic properties that will make it shrink when exposed to temperatures of 110°C (less than 10%) 145°C (at least 37.5%) that are usually exceeded by far in a post-impact fire.

Therefore, if fireproofness reqiurements were to be designed, it would most likely imply a complete redesign of cabin windows, with potentially trade-offs in terms of aircraft weight and/or mechanical resistance.

[100] The RRJ-95 airplane integrates the cabin windows of Saint-Gobain Sully French manufacturer. See page 188 of the Report as well.

1.18.25 On the operation of the aircraft intercom system

The FCOM Section 2.23 reads the detailed description of the communications.

The intercom systems are subdivided into two primary ones:

- audio management system [AMS];
- passenger address and communication intercom system [PACIS].

The AMS is designed to control the radio equipment sound signals, for communication and navigation. The system enables the crew to use:

- all the radio communication and navigation equipment, installed on board, in the transmission/reception mode;
- the intercom system;
- the call system;
- the PACIS.

The PACIS ensures the communication between the flight crew, flight attendants and ground personnel, as well as the passengers address.

The PACIS integrates the following primary components:

- one passenger address amplifier;
- the communication terminal of the flight attendant to the forward service zone;
- the communication terminal of the flight attendant to the aft service zone;
- the tone signal generator;
- the loudspeakers network.

The PACIS enables the generation of several types of the tone signals:

- the call of the flight attendant from the flight deck (a double tone signal);
- the call of the flight attendant by a passenger (a high-pitched tone signal);
- the pressing of the EMER key (a double tone signal);
- the FASTEN SEATBELTS or NO SMOKING signal (a high-pitched tone signal).

Into the PACIS the communication priority is integrated as follows:

- the flight crew;
- the flight attendant to the forward service zone.
- the flight attendant to the aft service zone.
- passenger address and entertainment system.

The AMS incorporates inter alia three identical sound control panels (these to the PIC, F/O and additional duty station). The control panels are similar (Fig. 134), not interconnected (the information exchange between the panels is not enabled). The FCOM Section 2.23.20 presents the detailed description of the control panel elements.

Fig. 134. The exterior of the ACP control panel

To select any communication channel for transmission the associated rectangular pushbutton should be pressed on ACP, its will then be lighted in green. To deselect the pushbutton should be pressed again, the light will then go out. Similarly the other communication channel may be selected, at that the the previously selected one will be deactivated automatically. It is one communication channel only that may be at once selected for transmission. The physical transmission of the message via one of the selected communication channels can be proceeded in one of three ways. The following should be pressed and held (the message is transmitted as long as the key is held pressed in the transmission position)[101]:

- the PTT pushbutton on the sidestick (Fig. 135), or;
- the PTT pushbutton on the hand microphone (Fig. 135), or;
- the INT/RAD switch on ACP in the RAD position (Fig. 134, position 4).

[101] At the additional flight crewbember jumpseat only the third of the stated ways is enabled.

Fig. 135. The allocation of the PTT pushbuttons on the sidestick and hand microphone

Note: *The INT/RAD switch on ACP can be set in one of three positions:*

- *INT – to maintain the intercommunication. The switch is locked in this position. When in this position and the released one of the INT volume knob[102] the flight crew intercommunication is carried out with the headset microphone without pressing the PTT pushbutton on the sidestick.*
- *NEUTRAL – the switch is locked in this position. The system functions on the reception only. The transmission is turned off.*
- *RAD – to maintain the transmission via the selected communication channel. The switch is not locked in this position. The message will be transmitted until the switch is forcibly held in the transmission position. When released, the switch moves to the NEUTRAL position.*

If the INT/RAD switch is positioned INT, and the pilot presses the PTT pushbutton on the sidestick or hand microphone, then the priority is given to the pushbuttons on the sidestick or hand microphone.

To monitor any communication channel in the headphones a crewmember should release the associated volume knob. The volume knob is lighted when released. By rotating the released volume knob the volume of the associated channel is changed. Another pressing of the volume knob (it is recessed) disconnects the associated reception channel. Several channels can be selected at once for reception with the individual volume adjustment. The channel, selected for transmission, at this flight crewmember is not automatically set for reception, to accomplish self-monitoring the associated volume knob should be released for reception.

In this way the transmission of messages via any communication channel is carried out uniformly. For instance to communicate with flight attendants the flight crewmember should press the CAB tramsmission rectangular button (Fig. 134, position 1). It will be lighted in green. The headset (oxygen mask) microphone and the hand microphone can be used to transmit the message to the cabin crew by the ways, described here above. To ensure the reception of the voice message from the cabin crew one should release the CAB volume knob (Fig. 134, position 2). The rotation of the volume knob enables the volume change of the message, received from the flight attendants.

Note: *With the CAB button the general call of the cabin crew to the forward and aft service zones is enabled. The individual call of the cabin crew in the forward or aft service zones is carried out with the FWD or AFT buttons on the CALLS*

[102] On Fig. 134 these are the round knobs of the second (lower) row under the associated inscriptions (the name of the communication channel).

control panel[103] *(* *Fig.* 136*). At that these buttons actually enable the Call Me Back function, that is they send the request to a flight attendant at the associated station to call the flight crew.*

Fig. 136. The exterior of the individual calls control panel

Meanwhile, there are several exceptions to the above mentioned message transmission rules. One of them is attributable to the use of the PA/Passenger Address transmission button by the flight cremembers. This button is not locked for transmission, but operates on the PUSH-TO-TALK principle. To address passengers via the hand microphone one should hold pressed the PTT pushbutton on hand microphone at the pressed PA button. To address passengers via headset (or the oxygen mask microphone) at the pressed PA button the holding of the INT/RAD in the RAD position or the PTT pushbutton on the sidestick is not required.

The PACIS integrates two flight attendants’ communication terminals (Fig. 137), which are allocated as follows:

- at the forward flight attendant duty station (the forward communication terminal);
- at the aft flight attendant duty station (the aft communication terminal).

[103] It is not every aircraft that this feature is implemented to. It had been integrated on the RA-89098 airplane.

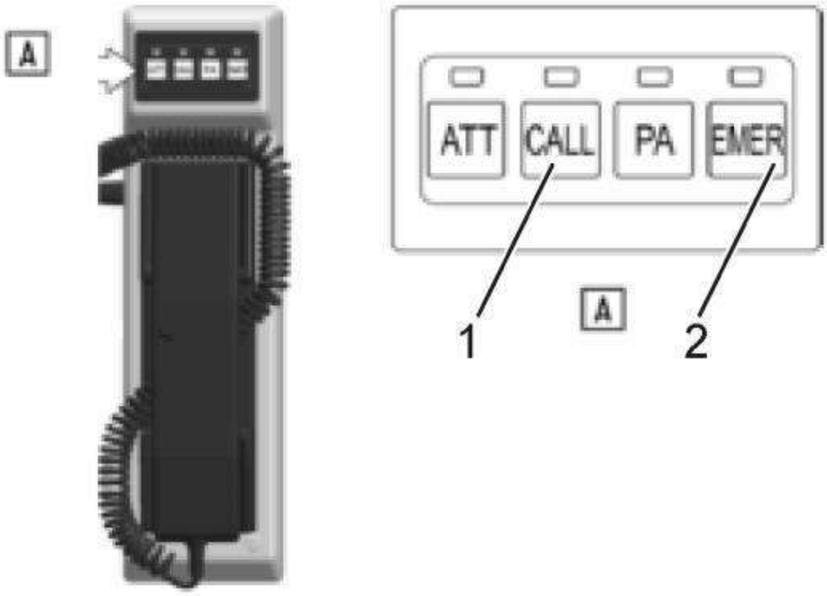


Fig. 137. The exterior of the flight attendant communication terminal

The flight attendant communication is enabled with the pickup of the phone receiver from the phone set support and can be carried out targetedly, circularly and in the passenger address mode. The control with the buttons is only possible at the receiver removed from the support.

The ATT button ensures the communication between the flight attendant terminals, allocated in the front and rear compartments. The light turns green when the call is answered or the contact is established.

The CALL button is designed to contact the flight deck. The light turns green when the call is answered or the contact is established. If a flight attendant answers the flight crew's call (the flight crew has selected the CAB button for transmission), then he/she just picks up the receiver (without the additional press of the CALL button) and talks «as on the phone». If he/she wants to call the flight crew, including for complying with the flight crew Call Me Back request, then he/she should pick up the receiver and press the CALL button. At pressing the button the following sound alert and annunciation are triggered:

at the flight deck:

- the amber ATT inscription lights up and flashes on all the ACP control panels;
- the sound double tone signal is active;

at the service zone:

- the green light above the CALL button[104] on the communication terminal is ON.

When sound information is transmitted simultaneously by several users, it will be mixed.

[104] The operational documentation incorrectly reads that at the service zone the sound double tone signal turns active.

The PA button enables the information address to the passengers. To transmit the message after the PA button selection (pressing) the PTT pushbutton, allocated on the inside of the phone receiver, should be pressed and held. The PA green light is ON at the transmission of the message (the pressed PTT pushbutton on the phone receiver).

The EMER button (the emergency call of the flight deck) is to establish the contact between the flight and cabin crewmembers. The flashing red light signals the emergency call. At pressing of the EMER (Emergency) button the following sound alert and annunciation are triggered:

at the flight deck:

- on all the ACP control panels the amber ATT light above the EMER button is ON and flashing;
- the sound double tone signal is active;

at the service zone:

- on the communication terminal the red light above the EMER button is ON and flashing;
- on both annunciators the red light is ON[105];
- the sound double tone signal is active.

The flight crew can press the EMER button as well on the ACP control panel. The pressing of this button by the flight or cabin crew enables the communication «emergency mode». The PIC and F/O's headsets, the cabin crew and ground personnel communication terminals are connected to the aircraft intercom. All the users talk «as on the phone», there is no need for the flight crew to apply the PTT. With that to monitor the messages by flight attendants the flight crewmembers should release their CAB volume knobs. The EMER mode can be cancelled via this control panel only, which it had been activated on.

The CVR enables the record of the sound data by four record channels: the first channel is to the additional duty station at the flight deck, the second one is to the F/O, the third channel is to the PIC, the fourth one is an open microphone. As for the first three channels the information is recorded that is delivered to the headphones of the respective flight crewmember (given the set volume level by every channel under monitoring) plus his/her own utterances, spoken out to the headset (oxygen mask) microphone or to the hand microphone. The record of his/her «own» utterances is ensured irrespective of the actual PTT pushbutton (not) pressing. Through the open microphone channel the sound environment at the flight deck is recorded. To enable the reception of the sound signals inside the cockpit one non-directional microphone is installed. The sound signals are delivered to the cockpit via the loudspeakers. A total of two loudspeakers are installed

[105] See the Cabin Crew Manual Section 03.35, page 3 for details.

at the flight deck (these at the PIC and F/O). The use of one or another loudspeaker and the output sound level are adjusted with the SPKR volume knobs (Fig. 134, position 13) on the PIC and F/O ACP. The documents do not provide for the record of the sound environment at the flight attendant duty stations.

As after the air accident the flight and cabin crewmembers complained of the intercom operation, the investigation team carried out the associated analysis. Its results are given in the Table here below. Through this table some utterances or their segments, which had not been delivered at the transmission or had been transmitted incomplete, are highlighted with grey.

UTC (the beginning of an utterance)	User	The content of radio communication, the number designates the CVR record channel number. Channel 1 to the additional flight crewmember is not stated, as there had been no third occupant on the jumpseat at the flight deck.	Remarks
14:16:55.3	CFA	2. – 3. – 4. Excuse me, please, (illeg.).	Low level of the record. The CFA may have been at the cockpit, the dialogue had been held without the use of the communication equipment. It has not been possible to determine the ACP configuration.
14:16:58.1	PIC	2. – 3. – 4. (I'm all for) (illeg.) close.	Low level of the record. The CFA may have been at the cockpit, the dialogue had been held without the use of the communication equipment. It has not been possible to determine the ACP configuration.
14:38:28.8	CFA	2. – 3. – 4. (Captain) 7 seats (are not occupied).	Low level of the record. The CFA may have been at the cockpit, the dialogue had been held without the use of the communication equipment. It has not been possible to determine the ACP configuration.
14:38:32.4	PIC	2. – 3. – 4. We're closing. Two hours trip.	Low level of the record. The CFA may have been at the cockpit, the dialogue had been held without the use of the communication equipment. It has not been possible to determine the ACP configuration.

14:38:52.3	PIC	*At 14:38:49.7 – the electrical circuit closure double impulse* 2. – 3. Good afternoon, ladies and gentlemen, this is your captain speaking, my name is …, I welcome you on board the Aeroflot airplane, one of the world's oldest and best known airline. In March 2019 Aeroflot turned 96 years. Our aircraft fleet is one of the world's newest. Today our flight is en route from Moscow Sheremetyevo to Murmansk. Set yourself up for a nice journey, the flight time will be two hours straight. I'm sure you'll enjoy the journey with Aeroflot, thank you for joining us. I wish you a pleasant flight. *This announcement is repeated in English further on.* 4. – *14:39:38 the electrical circuit opening single impulse*	**ACP LEFT PIC** The pressing and holding the PA transmission button. The PA volume knob is released (on reception) . **ACP RIGHT F/O** The utterance is not audible on the F/O channel. The PA volume knob is not released. The utterance is not audible on channel 4, which may be due to the insufficient level of the «desired signal/background noise» at the open microphone input.

14:39:46.1	CFA	*2. [1-1-3-0. Aeroflot 1-1-3-0 Sheremetyevo-Apron.]* *3. [1-1-3-0. Aeroflot 1-1-3-0 Sheremetyevo-Apron.]* Attention cabin crew – to set the doors to automatic mode, doors ARMED and cross-check. 4. –	**Forward communication terminal** The F/A applied the PA+PTT buttons. **ACP LEFT PIC** The PA volume knob is released. The utterance is not audible on channel 4, the SPKR volume knob is nor released or released, but the volume level is set to the value, insufficient to record the signal on the open microphone channel. The VHF radio station volume knob[106], set on the Sheremetyevo-Apron frequency, is released. **ACP RIGHT F/O** The utterance is not audible on the F/O channel. The PA volume knob is not released. The VHF radio station volume knob, set on the Sheremetyevo-Apron frequency, is released. On both PIC and F/O channels the external radio contact is audible, that is the respective volume knobs had been released.

[106] At this stage it was most probably the VHF1 radio.

14:40:18.8	CFA	2. – 3. Ladies and gentlemen, my name is Kseniya, I am a chief flight attendant, I welcome you on board our Sukhoi Superjet aircraft, which has been named after a prominent poet... 4. –	**Forward communication terminal** The F/A applied PA+PTT buttons. **ACP LEFT PIC** The PA volume knob is released. The utterance is not audible on channel 4, the SPKR volume knob is nor released or released, but the volume level is set to the value, insufficient to record the signal on the open microphone channel. The message record had been interrupted in the middle of the utterance, which is indicative of pressing the PA volume knob. **ACP RIGHT F/O** The utterance is not audible on the F/O channel. The PA volume knob is not released.
15:11:55.4		2. F1 sound signal = 550 Hz, F2=450 Hz. 3. F1 sound signal = 550 Hz, F2=450 Hz. 4.-	Double tone signal – the F/A call by the flight crew. The flight crew pressed the CAB call button on the ACP or the FWD button on the CALLS panel[107]. The level of the signal is low as if it had been delivering from the service zone (from the F/As). The operational logic of the communications, outlined in the documentation, does not explain the record of this signal. In the previous flight of this aircraft the record of the similar signals had been proceeded as well.

[107] By the PIC's explanation it had been the CAB button that he applied.

15:12:08.1		2. F1 sound signal = 550 Hz, F2=450 Hz. 3. F1 sound signal = 550 Hz, F2=450 Hz. 4.-	Double tone signal – the F/A call by the flight crew. The flight crew pressed the CAB call button on the ACP or the FWD button on the CALLS panel. The level of the signal is low as if it had been delivering from the service zone (from the F/As). The operational logic of the communications, outlined in the documentation, does not explain the record of this signal. In the previous flight of this aircraft the record of the similar signals had been proceeded as well.
15:12:14.8		2. F1 sound signal = 550 Hz, F2=450 Hz. 3. F1 sound signal = 550 Hz, F2=450 Hz. 4. F1 sound signal = 550 Hz, F2=450 Hz.	The F/A pressed the CALL button on the communication terminal. At the flight deck the double tone signal is clearly audible.
15:12:16.1	CFA	*The following sentence is uttered against the sound signal, indicated here above.* 2. – 3. Kseniya. 4. Kseniya.	**Forward communication terminal** The chief F/A is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The SPKR volume knob is released, the volume level is sufficient to record the signal on the open microphone channel. **ACP RIGHT F/O** It has not been possible to determine the ACP configuration.

15:12:17.0	PIC	*At 15:12:16,7 – the electrical circuit closure impulse from pressing the PTT.* 2. Kse 3. Kseniya. 4. (illeg.) *At 15:12:17,1 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton[108]. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT F/O** The CAB volume knob is released. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. ACP to ensure the communication between the crewmembers without using PTT are not set.
15:12:18.1	PIC	*There is no the PTT electrical circuit closure impulse at the region prior to the utterance.* 2. – 3. Ksenya. 4. (Ksenya).	The PIC had not pressed PTT. The PIC utters the sentence not loud enough to have it recorded clearly «directly» on the open microphone channel. ACP to ensure the communication between the crewmembers without using PTT are not set.

[108] By the PIC's explanation there and further it had been the sidestick PTT pushbutton that he applied to transmit the messages.

15:12:19.9	CFA	2. – 3. Go ahead. 4. Go ahead.	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The SPKR volume knob is released, the volume level is sufficient to record the signal on the open microphone channel. **ACP RIGHT F/O** It has not been possible to determine the ACP configuration.

15:12:20.8	PIC	*At 15:12:20,8 – the electrical circuit closure impulse from pressing the PTT.* 2. – 3. Can you hear me, can't you? 4. – *At 15:12:20,9 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT F/O** It has not been possible to determine the configuration. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:12:24.6	CFA	2. – 3. Denis. 4. Denis.	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The SPKR volume knob is released, the volume level is sufficient to record the signal on the open microphone channel. **ACP RIGHT F/O** It has not been possible to determine the configuration.

15:12:26.5	PIC	*At 15:12:26,5 – the electrical circuit closure impulse from pressing the PTT.* 2. Can you hear me, can’t you? 3. Can you hear me, can’t you? 4. – *At 15:12:27,2 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT 2П** The CAB volume knob is released. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:12:27.,3	CFA	2. *…[Sheremetyevo…]* 3. Yes, I can hear you now. 4. Yes, I can hear you now.	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The SPKR volume knob is released, the volume level is sufficient to record the signal on the open microphone channel. **ACP RIGHT F/O** External radio contact, the volume knob to the respective VHF radio[109] is released.

[109] At this stage it was most probably VHF2 radio.

15:12:30.2	PIC	*At 15:12:30,1 – the electrical circuit closure impulse from pressing the PTT.* 2. Well, we return 3. Well, we are returning 4. – *At 15:12:31,0 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT F/O** The CAB volume knob is released. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:12:32.4	PIC	*At 15:12:32,4 – the electrical circuit closure impulse from pressing the PTT.* 2. It is not the emergency one, nothing, just 3. It is not the emergency one, nothing, just returning. 4. – *At 15:12:33,6 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT 2П** The CAB volume knob is released. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:12:35.0	PIC	*At 15:12:35,0 – the electrical circuit closure impulse from pressing the PTT.* 2. Returning we are 3. Returning, we are in trouble 4. – *At 15:12:36,1 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. **ACP RIGHT F/O** The CAB volume knob is released. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:12:37.9	PIC	*At 15:12:37,8 – the electrical circuit closure impulse from pressing the PTT.* 2. Hullo, can you hear? The communications and control issues. *[Aeroflot 14-92.]* 3. Hullo, can you hear? The communications and control issues. *[Aeroflot 14-92.]* 4. – *At 15:12:41,5 – the electrical circuit opening impulse from releasing the PTT.*	**ACP LEFT PIC** The CAB transmission button is activated, the pressing of the sidestick PPT pushbutton. The release of the PTT pushbutton had occurred before the end of the utterance. The SPKR volume knob is either pressed or released, but the volume level is insufficient to record the signal on the open microphone channel. The PIC utters the sentence not loud enough to have it recorded «directly» on the open microphone channel. The volume knob to the respective VHF radio is released. **ACP RIGHT F/O** The CAB volume knob is released. The volume knob to the respective VHF radio is released.

15:12:40.5	CFA	2. *[Aeroflot 14-92 flight level 6-0.]* 3. Well, what were the reasons? The technical ones? *[Aeroflot 14-92 flight level 6-0.]* *4. [Aeroflot 14-92] (illeg.).*	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The volume knob to the respective VHF radio is released. **ACP RIGHT F/O** The volume knob to the respective VHF radio is released. The SPKR volume knob is released at one of the pilots, the volume level is sufficient to record the external radio contact on the open microphone channel.
15:12:46.6	CFA	2. *[Descending 900 meters, QFE 9-8-9, 20.]* 3. (That's it) I did not hear you, got it, due to technical issues. 4. (That's it) I did not hear you, got it, due to technical issues.	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. The SPKR volume knob is released, the volume level is sufficient to record the signal on the open microphone channel. **ACP RIGHT F/O** The volume knob to the respective VHF radio is released.

15:30:15.2		*The beginning of the video inside the passenger cabin (the 8A seat)*	
15:30:26.1		*The beginning of the video inside the passenger cabin (the 10F seat)*	
15:30:28.1		2. F1 sound signal = 550 Hz, F2=450 Hz. 3. F1 sound signal = 550 Hz, F2=450 Hz. 4. F1 sound signal = 550 Hz, F2=450 Hz..	The pressing - by the CFA most likely - of the CALL button. The sound signal is not audible at the passengers' cell phones videos.
15:30:28.7	F/O	2. Smell of fuel. 3. – 4. Smell of fuel.	**ACP LEFT PIC** It has not been possible to determine the configuration. **ACP RIGHT F/O** It has not been possible to determine the configuration. The sentence is uttered by the F/O loud enough to have it recorded «directly» on the open microphone channel. ACP to ensure the communication between the crewmembers without using PTT are not set.

15:30:30.4	CFA	2. *[…braking.]* Fire on board. *[Sound signal 1000 Hz]* 3. Fire on board. *[Sound signal 1000 Hz]* 4. *[Sound signal 1000 Hz]*	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. **ACP RIGHT F/O** The CAB volume knob is released. The SPKR volume knobs are either pressed or released, but the volume level is sufficient to record the signal on the open microphone channel against the active sound warnings.
15:30:33.7	CFA	2. (Fire). 3. Fire. 4. –	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. **ACP RIGHT F/O** The CAB volume knob is released. The SPKR volume knobs are either pressed or released, but the volume level is sufficient to record the signal on the open microphone channel against the active sound warnings.

15:30:35.4		2. F=3100 Hz lavatory smoke signal 3. F=3100 Hz lavatory smoke signal 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2, 3, 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. At the videos by the passengers' cell phones the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.
15:30:36.9		2. F=3100 Hz lavatory smoke signal 3. F=3100 Hz lavatory smoke signal 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2, 3, 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. At the videos by the passengers' cell phones the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.

15:30:37.2	F/O	2. Attention crew! On station. Attention crew! On station. 3. Attention crew! On station. Attention crew! On station. 4. Attention crew! On station. Attention crew! On station.	As per the FDR record, within the interval of this message transmission the discrete signal is recorded, indicating the initiation of the external radio contact via VHF2. At the videos by the passengers' cell phones the sentence is not audible. **ACP LEFT PIC** The VHF2 radio volume knob is released. **ACP RIGHT F/O** The VHF2 transmission button is activated, the holding of the INT/RAD switch in the RAD position[110]. The sentence is uttered loud enough to have it recorded «directly» on the open microphone channel, or the SPKR volume knob is released at one of the pilots and the volume level is sufficient to have it recorded.
15:30:37.3		2. F1 sound signal = 550 Hz, F2 = 450 Hz. 3. F1 sound signal = 550 Hz, F2 = 450 Hz. 4. F1 sound signal = 550 Hz, F2 = 450 Hz.	It is recorded at the videos from the passenger cabin. The pressing of the EMER button by one of the flight/cabin crewmembers. The initiation of the signal aligns with the lavatory smoke warning record interruption on the PIC channel.

[110] By the F/O's explanation it was this very switch that he had applied to transmit messages.

15:30:39.1		2. F=3100 Hz lavatory smoke signal 3. – 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2 and 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. It is not audible on the PIC channel. At the videos by the passengers' cell phones the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.
15:30:40.1		2. F=3100 Hz lavatory smoke signal 3. – 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2 and 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. It is not audible on the PIC channel. At the videos by the passengers' cell phones the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.

15:30:40.2	F/O	2. Evacuation. 3. Evacuation. 4. Evacuation.	At videos by the passengers' cell phones the sentence is not audible. It has not been possible to unambiguously determine the ACP configuration. The utterance is audible on the PIC channel as well at the active EMER mode. The sentence is uttered loud enough to have it recorded «directly» on the open microphone channel.
15:30:41.1	PIC	2. Emergency evacuation checklist. 3. Emergency evacuation checklist. 4. Emergency evacuation checklist.	At videos by the passengers' cell phones the sentence is not audible. It has not been possible to unambiguously determine the ACP configuration. The utterance is audible on the F/O channel as well at the active EMER mode. The sentence is uttered loud enough to have it recorded «directly» on the open microphone channel.
15:30:41.2		*The end of the video inside the passenger cabin (the 8A seat)*	

15:30:42.2		2. F=3100 Hz lavatory smoke signal 3. – 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2 and 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. It is not audible on the PIC channel. At the video by the passenger's cell phone the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.
15:30:43.4		2. F=3100 Hz lavatory smoke signal 3. – 4. F=3100 Hz lavatory smoke signal	It is hardly audible on channels 2 and 4, as if the signal had been delivering from the service zone (similarly to the time points, mentioned here above: 15:11:55,4 and 15:12:08,1), although it should have been clearly audible. It is not audible on the PIC channel. At the video by the passenger's cell phone the warning can be heard. The operational logic of the communications, outlined in the documentation, does not explain the record of this signal.

15:30:43.8	F/O	2. Emergency evacuation checklist. 3. Emergency evacuation checklist. 4. Emergency evacuation checklist.	At the video by the passenger's cell phone the warning is not audible. It has not been possible to unambiguously determine the ACP configuration. Most probably the ACP are set to ensure the communication between the crewmembers without using PTT. The sentence is uttered loud enough to have it recorded «directly» on the open microphone channel, or the SPKR volume knob is released at one of the pilots and the volume level is sufficient to have it recorded.
15:30:45.5		2. F1= 550 Hz, F2=450 Hz. 3. F1= 550 Hz, F2=450 Hz. 4. F1= 550 Hz, F2=450 Hz.	The pressing – by the F/A at the aft service zone most probably – of the CALL button. At the video by the passenger's cell phone the warning is not audible.
15:30:45.5	F/A	2. *[…alternate…] [the fragment of the synthetic voice]* 3. We are on fire. 4. *[…alternate…] [the fragment of the synthetic voice]*	**Aft communication terminal** The F/A at the aft service zone is transmitting the message via the phone receiver microphone without additionally pressing buttons. **ACP LEFT PIC** The CAB volume knob is released. **ACP RIGHT F/O** It has not been possible to determine the configuration.

15:30:47.2		*The end of the video inside the passenger cabin (the 10F seat)*	
15:30:47.9	F/O	2. [It] fell out. *[Intermittent sound signal F1=900 Hz, F2=1600 Hz.]* 3. *[Intermittent sound signal F1=900 Hz, F2=1600 Hz.]* 4. [It] fell out. ***[****Intermittent sound signal F1=900 Hz, F2=1600 Hz.]*	It has not been possible to unambiguously determine the ACP configuration. Most probably the ACP are set to ensure the communication between the crewmembers without using PTT. The sentence is uttered loud enough to have it recorded «directly» on the open microphone channel.
15:30:48.7	CFA	2. Seatbelts off, leave everything, get out (*first in Russian and repeated in English afterwards*). 3. Seatbelts off, leave everything, get out (*first in Russian and repeated in English afterwards*). 4. –	**Forward communication terminal** The CFA is transmitting the message via the phone receiver microphone without additionally pressing buttons. As the PA button was not pressed, the announcement had been delivered to the flight deck instead of passenger cabin. **ACP LEFT PIC** The CAB volume knob is released. **ACP RIGHT F/O** The CAB volume knob is released.

15:30:52.0	F/O	2. Evacuation. 3. – 4. Evacuation.	**ACP LEFT PIC** It has not been possible to determine the configuration. **ACP RIGHT F/O** It has not been possible to determine the configuration. The sentence is uttered by the F/O loud enough to have it recorded «directly» on the open microphone channel. The ACP to ensure the communication between the crewmembers without using PTT are not set.

From the table above the following can be concluded:

- at the stage of the flight after the aircraft had been exposed to the atmospheric electricity at the internal communication between the PIC and CFA there are the PIC's utterances and their segments that, most probably, had not been delivered to the flight attendant. In reverse, most likely, all the utterances had passed in full. The non-delivery of a segment of information from the PIC to the F/A is related to the disconnection of the communication channel, the switching of which is carried out by the PIC with pressing the sidestick PTT pushbutton. The investigation team has not revealed any signs of the failed operation of either the PIC's sidestick or the PTT pushbutton in particular. More than likely the non-delivery of the part of information is associated with the non-pressing or the early PTT pushbutton release by the PIC. The practice of air accident investigation is the evidence that this may result from the pilot's non-optimal psychoemotional condition;
- at the stage of «the landing roll» and after the aircraft came to stop the information from the cabin crew to the flight one (the reports on fire) had been delivered as assigned from the flight attendants' duty stations both at the forward and aft segments of the cabin;
- the F/O's command *«Attention crew! On station! Attention crew! On station!»,* addressed to the flight attendants, had been aired (on the external radio communication) and could not have been heard by them;
- the command by the CFA *«Seatbelts off, leave everything, get out»* had been transmitted to the flight deck, and not to the passenger cabin via the PACIS. This command could have been only heard by the passengers, allocated next to the forward service zone (the CFA).

1.18.26 On the in-flight serviceability of the VDR

Three independent VHF communication systems are installed on the RRJ-95 aircraft that enable the voice communication of flight crewmembers with ground control services and the crewmembers to other aircraft. The failure of one radio station is attributed as the MINOR failure condition, the total loss of two-way radio communication is classified as the MAJOR failure condition. The RRJ-95 flight documentation incorporates the relevant recommendations to the crew on the actions at the failure of the VHF communication systems.

The VHF transceiver unit had been tested, compliant to the DO-160D requirements under the appropriate category of resistance to atmospheric electricity. As per the available data into the operation of the RRJ-95 aircraft, there had been no previous events recorded of the radio communication systems equipment malfunction due to the exposure to lightning.

On the results of the performed certification activities, stated in the «Summary Report on the Establishment of Compliance of the RRJ-95B Aircraft Radio Communication Equipment with the Certification Basis Requirements» RRJ0000-RP-011-1310 document, the compliance of the radio communication system with the applicable requirements to the standards had been confirmed.

Section 1.16.7 reads the results of the examination of the VDR post-accident condition. This section provides a comprehensive analysis of the functioning of the VDR into the flight that ended up with the accident and their operation by the flight crewmembers.

On ground and in the progress of the flight till the airplane encountered lightning the flight crewmembers operated the VDR 1 for the external radio contact on the operating frequencies of the ATC units.

Between 15:07:13 and 15:08:05 the radio communication had been proceeded with the VDR 1 on the frequency of 122.7 MHz (Moscow-Approach). The radio reception had been interrupted at 15:08:10, when the aircraft, having performed the AFL1103 flight, reported to the ATC: «*AFL1103, good afternoon, heading 220…*».

The interruption of the radio reception had been a consequence of the VDR 1 failure due to the aircraft exposure to lightning. Several attempts by the flight crew to establish radio contact with the use of VDR 1 after the aircraft encountered atmospheric electricity had not been detected on the ATC recorders (the full list of these sentences is given in the Table here below), which indicates the VDR 1 transmission malfunction as well. With that the discrete signal, indicating the attempts to transmit the message via VDR 1 had been recorded by FDR even at the failure of the VDR itself.

Time	**Speaker**	**Content (CVR)**
15:08:32,3	F/O	PAN–PAN, PAN–PAN, PAN–PAN, Aeroflot 14-92, request vectoring, return.
15:08:44,0	F/O	Moscow-Approach, Aeroflot 14-92, PAN–PAN, PAN–PAN, PAN–PAN, request return.
15:10:41,5	PIC	Aeroflot 14-92.
15:10:45,6	PIC	With the second only.
15:10:48,7	F/O	Descending flight level 7-0, Aeroflot 14-92
15:13.47,0	F/O	Autopilot pushbutton…
15:18:44,6	PIC	A, Aeroflot...

Time	Speaker	Content (CVR)
15:26:39,6	F/O	Sheremetyevo-Tower, Aeroflot 14-92.
15:26:42,6	F/O	Sheremetyevo-Tower, Aeroflot 14-92.

The first successful radio contact after the aircraft encountered lightning had been established by the flight crew on the emergency frequency 121.5 MHz with the VDR 2 at 15:09:04: *«Sheremetyevo-Tower, Aeroflot 14-92, how you read?»*. This sentence is audible on the recorders to the ATC units.

The Moscow-Approach controller tried four times to contact the crew back on the 122.7 MHz operating frequency (at that the crew proceeded calls on the emergency frequency, these had been delivered to the controller). These responses by the controller are not audible (not recorded) on the CVR, as the indicated frequency had been set on neither of the serviceable VDR.

The two-way radio communication with Moscow Approach unit had been resumed at 15:09:35, when the controller responded to the crew on the 121, 5 MHz emergency frequency that had been set aboard on the VDR 2.

At 15:26:18 the Radar controller instructed to contact the Sheremetyevo Tower C2 sector ATC officer on the 131.5 MHz frequency. At 15:26:40 the F/O attempted to establish contact with the Tower controller on the operating frequency with the VDR 1, this contact had not been recorded on the ATC recorder, as the VDR 1 had been unserviceable. Further on the F/O resumed the use of the VDR 2 and at 15:27:02 called the controller on the operating frequency (131.5 MHz). This call is recorded on the ATC recorder, the Tower controller responded to the crew at 15:27:05 on the emergency frequency (121.5 MHz). Still the response of the controller is not recorded by the CVR, apparently because the emergency frequency at that moment had been set on neither of the serviceable VDRs.

Having not been called back by the controller, at 15:27:09 the F/O called him again via VDR 2. This call is not recorded by the ATC recorder. The analysis found that there was no record of the external radio communication initiation discrete signal by the FDR at that point of time, that is to say there had been no respective circuit switching, having caused the non-delivery of the sentence.

At 15:27:13 the PIC called the controller once again on the emergency frequency with VDR 2. This request had been recorded on the ATC recorder, still the controller had not responded, having been busy with the radio communication with another traffic on the operating frequency. At 15:27:18 the F/O once again called the controller with VDR 2, though again did not push the external radio communication pushbutton. At 15:27:24 the F/O once again called the controller with VDR 2 on the emergency frequency, on that one the call had been delivered and the controller responded on the emergency frequency as well.

In the Table here below it is the sentences or the parts of the sentences, highlighted with grey color, which had not been transmitted from the aircraft on the air (in other words they had not been delivered to the ATC officers). At all times the external radio contact discrete signal had not been recorded over the intervals, when the information had not been aired.

The time of the beginning	Speaker	Content
15:12:55,2	F/O	Descending 900, to the right 140, QFE 9-8-9, 24 left Aeroflot 14-92.
15:15:09,7	F/O	To the right 180, descending 600, Aeroflot 14-92.
15:15:40,5	F/O	Heading 190, approach 24 left Yankee cleared, Aeroflot 14-92.
15:17:01,0	F/O	To the right heading 210, Echo Echo 309, Aeroflot 14-92.
15:19:44,0	F/O	To the right 0-90, will tell further, Aeroflot 14-92.
15:20:57,2	F/O	A… To the right 110, yes if (possible) longer Aeroflot 14-92.
15:23:03,0	F/O	Ready, Aeroflot 14-92.
15:24:13,9	F/O	To the left 20, Aeroflot 14-92.
15:24:52,5	F/O	Approach ILS 24 left cleared, Aeroflot 14-92.
15:27:08,8	F/O	Sheremetyevo-Tower, Aeroflot 14-92.
15:27:17,8	F/O	Sheremetyevo-Tower, Aeroflot 14-92.
15:27:59,8	F/O	Cleared to land, 24, Aeroflot 14-92.

At the post-accident interviews the crewmembers claimed the unstable operation of the VDR 2 after the aircraft encountered lightning. Within the investigation the investigation team revealed no signs of the VDR2 failure. As explained by the F/O, after the airplane had been exposed to the atmospheric electricity he proceeded the external radio communication with the use of the INT / RAD switch on the ACP (Fig. 134), and not with the sidestick PTT pushbutton not to allow the inadvertent deflection of the sidestick. The feature of the use of the INT / RAD switch is that it is not locked in the RAD position, that is it should be enforced in this position throughout the information transmission. Most probably at times the F/O had not pressed the switch in, which had not enabled the communication channel switching. The air accident investigation practice is the evidence that this may be a consequence of the pilot’s non-optimal psychoemotional condition.

As for the FDR the External radio contact with VDR 3, External radio contact with HF 1 and External radio contact with HF 2 discrete signals had not been recorded that indicates the crew had not operated the radio stations in question for the radio communication.

1.18.27 On certain AFM, FCOM and FCTM provisions

The RRJ-95B FCOM Flight Crew Bulletin on the landing performance technique reads the following provisions to prevent the late flare (Fig. 138).

АЭРОФЛОТ RRJ-95 Руководство по летной эксплуатации	БЮЛЛЕТЕНЬ ДЛЯ ЛЕТНОГО ЭКИПАЖА	1.09.11 СТР. 7	
	ТЕХНИКА ВЫПОЛНЕНИЯ ПОСАДКИ		01/00

- Контролируйте скорость снижения до начала выравнивания (не допускайте увеличения скорости снижения).
- Начинайте выравнивание энергичным, в одно движение перемещением ручки управления самолетом (SS) "на себя" и удерживайте ручку SS в требуемом положении.
- Не допускайте перемещения ручки SS "от себя", после начала выравнивания.

AEROFLOT Russian Airlines	**Flight Crew Bulletin**	1.09.11 PAGE 7	
RRJ-95 FCTM	Technique of landing performance		01/00

- Control the rate of descent till the initiation of flare (do not allow the increase of the rate of descent).
- Initiate the flare with the dynamic, one step, back input of the sidestick and hold the sidestick in the required position.
- Avoid the forward sidestick repositioning after the initiation of flare.

Fig. 138. The RRJ-95 FCOM provisions on the prevention of late flare

As clarified by the representatives of the aircraft designer, the third item of the Procedure implies that the ***«forward» beyond neutral*** deflection of the sidestick is prohibited after the initiation of flare.

At that in the progress of the investigation the representatives of the Aeroflot, PJSC command and flight personnel expressed the position that the interpretation of the second and third items together may lead to understanding that after the aft sidestick input to initiate flare its further hold is required, at that ***the forward input*** (even ***with maintaining the general back input***) is not allowed.

The investigation team points out that the ***«repositioning»*** term in the third item may indeed result in such an understanding. To compare the Figure below presents the same provisions out of the FCTM to the A320 aircraft family, which are as well equipped with the sidesticks. At almost verbatim similarity of the recommended procedures at the A320 family FCTM the third item reads important clarification on the acceptability of reducing the magnitude of the sidestick aft input (the back-pressure release of the sidestick) after the initiation of flare that excludes the ambiguous interpretation of the recommended procedure.

A318/A319/A320/A321 FLIGHT CREW TECHNIQUES MANUAL	PROCEDURES NORMAL PROCEDURES STANDARD OPERATING PROCEDURES - LANDING

- The rate of descent must be controlled prior to the initiation of the flare (rate not increasing)
- Start the flare with positive (or "prompt") backpressure on the sidestick and holding as necessary
- Avoid forward stick movement once Flare initiated (releasing back-pressure is acceptable)

Fig. 139. The A320 family FCTM provisions on the prevention of late flare

The same section of the RRJ-95 FCOM integrates recommendations to the flight crew on the actions at the repeated aircraft separation (bouncing) at landing (Fig. 140). The investigation team marks that the cited recommendations may be efficient in a specific case only, when at the point of touchdown the pitch attitude does not tend to significantly alter (the pitch rate and pitch angular acceleration are close to zero). Generally it may be impossible to avoid «***the alteration of the pitch attitude»*** by retaining the sidestick at the point of touchdown. What's more in a number of cases (for instance at the sidestick position, substantially different of the trim one at the point of touchdown, or at the significant aircraft out-of-trim pitch) the sidestick retainment (keeping held) in pitch may result in the further adverse consequences.

1.09.11 СТР. 18		БЮЛЛЕТЕНЬ ДЛЯ ЛЕТНОГО ЭКИПАЖА	АЭРОФЛОТ Российские авиалинии
01/00		ТЕХНИКА ВЫПОЛНЕНИЯ ПОСАДКИ	RRJ-95 Руководство по летной эксплуатации

ОТДЕЛЕНИЕ САМОЛЁТА ОТ ВПП ПРИ ПОСАДКЕ

В случае незначительного отделения (менее 5 ft) самолета от ВПП после касания, зафиксируйте ручку SS в положении, достигнутом в момент касания, не допуская изменения угла тангажа и удерживая РУД в положении IDLE, завершите посадку. Не допускайте увеличение угла тангажа, особенно после грубого приземления с большой угловой скоростью по углу тангажа.

1.09.11 PAGE 18		Flight Crew Bulletin	AEROFLOT Russian Airlines
01/00		Technique of landing performance	RRJ-95 FCTM

THE AIRCRAFT BOUNCING AT TOUCHDOWN

In case of the light bounce (less than 5 ft) of the aircraft off the runway after touchdown, keep the sidestick retained in a position, attained at the point of touchdown, not allowing the pitch alteration and holding the TL in the IDLE position, complete the landing. Avoid the increase of pitch, especially after hard touchdown with a significant pitch rate.

Fig. 140. The RRJ-95 FCOM provisions on the counteracting of bouncing

The investigation team points out as well that the indication of the specific value (5 ft) as the criterion of the lightness of bouncing is of no common sense, as at this stage the pilot visually operates the airplane.

For comparison Fig. 141 shows similar provisions out of the A320 family FCTM. The investigation team believes that the recommendation on maintaining the pitch attitude without limiting retaining the sidestick is a more precise reflection of the physical meaning of the crew's actions, required to counteract the bouncing, however it does not cover the events of the intense alteration of pitch attitude at the point of touchdown either. Likewise the Airbus FCTM does not integrate the quantitative criteria of the bounce «lightness», which seems reasonable and appropriate.

A318/A319/A320/A321 **FLIGHT CREW TECHNIQUES MANUAL**	**PROCEDURES** **NORMAL PROCEDURES** STANDARD OPERATING PROCEDURES - LANDING

BOUNCING AT TOUCH DOWN

In case of light bounce, maintain the pitch attitude and complete the landing, while keeping the thrust at idle. Do not allow the pitch attitude to increase, particularly following a firm touch down with a high pitch rate.

Fig. 141. The A320 family FCTM provisions on the counteracting of bouncing

Note: *The sample review of the other aircraft documentation sections revealed that overwhelmingly only qualitative criteria are used as well for the description of the «degree of the bounce/the height of the consecutive separation» (light bounce, shallow bounce, high bounce, hard bounce). However the exceptions do exist. For instance the A220 aircraft[111] documentation reads the value of 4 ft.*

Altogether the investigation team points out the substantial gaps in the drafting of the RRJ- 95 aircraft documentation. For instance the content of the FCOM sections with the description of the FBWCS control laws is true for the A320 family, but not for the RRJ-95 aircraft.

1.18.28 On the peculiarities of the radio altitude record

As reported by the aircraft designer the principle of the radio altitude measurement (computation) had been determined by the condition that «0» is accomplished: at the pitch attitude of 6° to nose-up, the wheels to the MLG legs touch the ground and there is no WOW to the legs themselves. It is these values that are recorded by FDR. In light of the above stated, Fig. 142

[111] Earlier designated as Bombardier CSeries.

presents the recorded values of the radio altitude and their recomputation as to the different aircraft points:

- the values, recorded by FDR (the red color);
- the height of the MLG legs wheels (the dark blue color). This parameter becomes zero at the occurrence of the WOW discrete signal. With the increase of weight on the shock absorbers the values become negative;
- the height of CG (the maroon color);
- the height (attitude) of the pilot’s head (the green color).

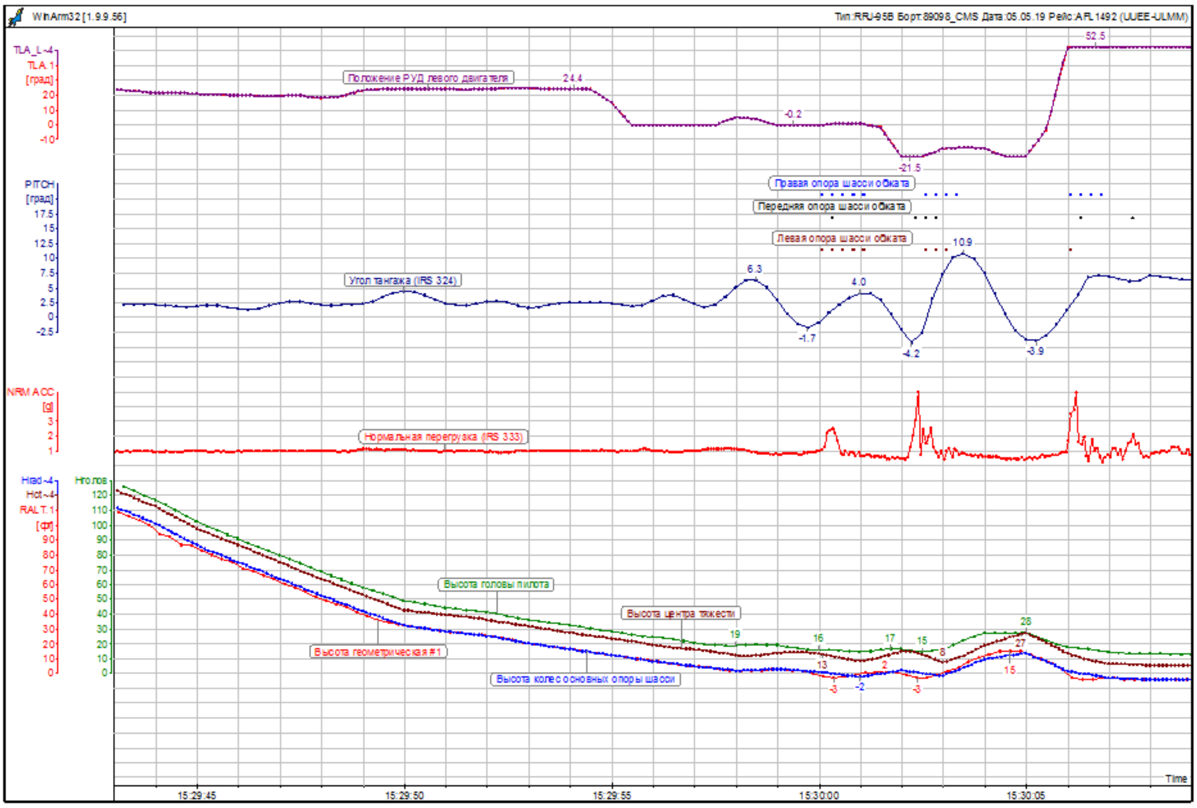


Fig. 142. The recorded and estimated values of the radio altitude

1.18.29 On the operation of the inert gas system into the flight that ended up with the accident

The inert gas system is designed to supply a reduced oxygen content air to the ullage above the fuel tanks to minimize the in-flight flammability of fuel vapors.

The basic principle of the system operation is to separate and remove the oxygen out of air through the membrane filters and to supply the nitrogen-enriched air to the fuel tanks.

The health monitoring of the system is automated, it does not require the interference of the crew.

The investigation team analyzed the condition and serviceability of the inert gas system into the flight that ended up with the accident. It has been determined that there had been no opening of the air supply valves out of the air bleed system to the separator, that is to say there had been no inert gas supply to the fuel tanks into the entire flight.

In accordance with the acting documents the schedule of the inert gas system condition monitoring is 7 days. As for the RRJ-95 aircraft the MMEL stipulates for the 7 days of operation of the aircraft with the unserviceable inert gas system.

The RA-89098 aircraft operational history analysis was the evidence that on May 4, 2019 the WO16298028 entry had been opened on the unserviceable condition of the inert gas system. The 47-00-00-710-801 ed. 02 Work had been carried out on the fault repair and the system had been permitted to return to operation. However as early as throughout the next flight the system had not operated from its start.

Further analysis found that the inert gas system failures had been recorded three more times in 2019 - on April 23, April 26 and April 27, 2019. To all three failure events based on the 47-519-13 procedure the AMM 47-00-00-710-801 works had been carried out with the stamps that after the performed works the system was authorized to the further operation. It is in 2018 as well that the inert gas system failure events had been repeatedly recorded.

There had been neither aircraft in-flight fire, nor the traces of fire inside the fuel tanks. As the air accident resulted in the fuel tanks ruptured unpressurized, at the operating inert gas system it had been impossible to maintain the required concentration of the nitrogen-enriched air in the ullage. Besides the aircraft had been exposed to the external fire that cannot be counteracted by the inert gas system.

Thus the unserviceability of the inert gas system could not have anyhow affected the outcome of the flight that ended up with the accident. Still the multiple recurrence of the failure indicates to certain difficulties in the technical operation of the aircraft of the type (see Section 1.6 of the Report as well).

1.18.30 The emergency evacuation SOP at the Airbus and Boeing aircraft

The A320 family

EMER EVAC

AIRCRAFT / PARKING BRK.................................STOP / ON
ATC (VHF 1).................................NOTIFY
CABIN CREW (PA).................................ALERT
ΔP (only if MAN CAB PR has been used).................................CHECK ZERO

- **If ΔP not at zero:**
  CAB PR MODE SEL.................................MAN
  V/S CTL.................................FULL UP

ALL ENG MASTERS.................................OFF
ALL FIRE pb (ENGs & APU).................................PUSH
ALL AGENTS (ENGs & APU).................................AS RQRD

- **If evacuation required:**
  EVACUATION.................................INITIATE

- **If evacuation not required:**
  CABIN CREW AND PASSENGERS (PA).................................NOTIFY

The B737 family

Evacuation

Condition: Evacuation is needed.

1	PARKING BRAKE. . . . . Set	C
2	Speedbrake lever . . . . DOWN	C
3	FLAP lever 40	F/O
4	Pressurization mode selector . . . . . MAN	F/O
5	Outflow VALVE switch . . . . Hold in OPEN until the outflow VALVE indication shows fully open to depressurize the airplane	F/O
6	If time allows, verify that the flaps are 40 before the engine start levers are moved to CUTOFF.	C
7	Engine start levers (both) . . . . . CUTOFF	C
8	Advise the cabin to evacuate.	C
9	Advise ATC.	F/O
10	Engine and APU fire switches (all) . . . . Override and pull	F/O
11	**If** an engine or APU fire is **observed or indicated**: Related fire switch. . . . . .Rotate to the stop and hold for 1 second	F/O

■ ■ ■ ■

1.18.31 On the sidestick inputs into takeoff run and landing roll

The RRJ-95 aircraft FCOM provides as follows on the sidestick inputs at the stages of takeoff run:

04.57 TAKEOFF

To counteract the nose-up moment from the setting of takeoff thrust apply sidestick forward by ½ of travel and keep it in this position until VR is reached.

Still the airline SOP read a slightly different wording on the sidestick input on takeoff:

2.3.7 Takeoff procedure

SIDESTICK……………….…………1/2 DOWN

The PF shall apply forward sidestick by at least half travel.

According to the airline the supplied flight data monitoring tools (as per the Operational Monitoring Algorithms Catalogue, approved by the SSJ Program Chief Designer) at the sidestick input by less than 50% of travel at takeoff run emit the notice (generate the occurrence). To eliminate the generation of occurrences at the stage of takeoff the additional information had been introduced in the OM that the sidestick is to be applied by *«at least»* ½ of the travel. Meanwhile, the manufacturer does not anyhow limits the application of the sidestick full travel input at takeoff run and many pilots just deflect the sidestick by the full travel. This position of the sidestick significantly increases the load, applied on the NLG and - as for the rough runways – may induce unfavorable pitch oscillations.

As for the RRJ-95 aircraft the instrumental monitoring of the sidestick position is only available with the F/CTL memo page that may be opened at the MFD. By contrast, right into the takeoff run the navigation data are displayed on MFD, at that with the activation of the F/CTL memo page instead of the navigation data the flight crew situational awareness will be substantially degraded and in this way it is not used in operation. That is to say it is virtually impossible to instrumentally monitor the sidestick position into the takeoff run[112].

Into the landing roll the FCOM suggests that any sidestick input «should be avoided»:

04.80 LANDING

At the landing roll one should avoid the sidestick inputs beyond neutral.

The airline SOP do not integrate any provisions in this respect at all.

The investigation team observes that through the text above of the indicated FCOM Section there is a caution for the flight crew that after touchdown they shall *«be ready to counteract the nose-up moment that is induced by the deployment of speedbrakes and spoilers»*. The provisions in question are in conflict with each other, because to counteract the nose-up moment the sidestick should be applied to nose-down.

In NORMAL MODE the nose-up moment from the deployment of speedbrakes and spoilers is substantially less than in DIRECT MODE. Fig. 68 shows that after the deployment of speedbrakes at the neutral sidestick the landing roll until the speeds of about 90 kt were reached had been proceeded with no steady WOW to NLG.

[112] As to the aircraft by some other manufacturers the sidestick position is indicated on the PFD.

However, the full forward sidestick input at the landing roll contributes to the increased load application on the airplane structure (the NLG primarily) and the adverse pitch oscillations (Fig. 81).

1.19 Useful or effective investigation techniques

No new methods have been used into the subject investigation.

2. Analysis

2.1. Description of the flight

On May 05, 2019 the Aeroflot, PJSC flight crew out of the PIC and F/O was performing the scheduled passenger flight SU-1492 aboard the RRJ-95B RA-89098 aircraft en route from Sheremetyevo airport (UUEE) to Murmansk airport (ULMM). From the previous flight that had been operated by another flight crew, the airplane arrived at 10:41. There had been no comments on the aircraft technical condition.

The F/O following his arrival at Sheremetyevo airport (the arrival was recorded at 12:50 by the Akkord complex of information systems) underwent the medical check, was given two sets of the electronic tablets (EFB) and the required documents (OFP, NOTAM, MEL Reporting Form). At 13:11, the F/O obtained meteorological information, after that he initiated the preflight preparations, compliant to the SOP.

At about 1 hr 30 min before SDT[113] the PIC arrived at the briefing room, got acquainted with the F/O[114], underwent medical check, took the flight assignment and initiated the preflight preparations. As initially it was the F/O to obtain the weather information, the PIC at 13:39 requested the actual weather information at the meteorologist.

At 14:16:42, the crew proceeded with the performance of the preflight checks at the flight deck.

At 14:19:50, the PIC, having acted as a PF into the subject flight, started the TAKEOFF BRIEFING that included the items of the BEFORE LANDING briefing in the event of immediate return after takeoff[115]. As per the CVR data, inter alia, the crew noted: *«…clear status[116], no MEL restrictions, no NOTAM restrictions…»*. Further on the crew determined the actions at the potential emergencies after takeoff: *«…engine out SID straight ahead hold at…»* and *«In case immediately return… TALUK, MAYDAY»*.

The preflight checks were completed at 14:22:50, the checklist PREFLIGHT[117] Section was carried out afterwards.

Between 14:25:40 and 14:27:20, the crew monitored the ALFA ATIS information, and then from 14:28:00 to 14:31:22, the BRAVO ATIS one*: «...for departure runway in use 24 Central, wet, braking action standard 0-45. Transition level 60, expect RVSM on runway, caution birds. Weather. Wind: 140 degrees 3 gusts 6. Visibility more than 10 km, clouds few cumulonimbus at 1800,*

[113] According to the schedule the SU-1492 flight was to depart at 14:50.
[114] As per the information available, up to the day of the accident the PIC and F/O had never operated together in one crew.
[115] At that the crew had not monitored the ATIS information for landing.
[116] It means there were no failed systems.
[117] The titles of the checklist Sections in English are stated as per the airline OM.

temperature 17, dew point 13, QFE 7-4-2 millimeters, 9-8-9 hectopascals, QNH 1-0-1-1 hectopascals, Runway 24 Central, QFE 7-4-2 millimeters, 9-8-9 hectopascals, no significant changes». These weather conditions had not impeded the performance of takeoff.

At 14:35:25 the Sheremetyevo Delivery controller on the crew request relayed the SQUAWK and SID: «*Aeroflot 1-4-9-2, Sheremetyevo - Delivery, good evening, cleared to Murmansk, runway 2-4 Central, Kilo November 2-4 Echo departure, SQUAWK 2-1-4-7».*

At the discussion of the relayed KN 24E SID[118] (see Fig. 28 at Section 1.10 of the Report) the PIC spoke out the presence of clutters: «*It's all the same, to the right, just there is a clutter in the back. So we're even faster».* The aircraft had been allocated at stand # 107 with the heading of 245°. By the PIC's evidence, he had observed the cloud visually, the weather radar had not been turned on while the aircraft had been on stand. Nevertheless as per the FDR data, the scale of the PIC's ND, which displays the weather radar data, at the subject time interval had been changing from 40 nm (74 km) to 5 nm (9.3 km).

Shortly after, at 14:36:54, the PIC once again commented on the change of SID: *«Yes, the time is the same», «One minute, it seems to me».*

At 14:37:14 the PIC expressed displeasure with the delay: *«What are we waiting for, I cannot understand? ».*

At about 14:37:30 the loadsheet was brought aboard the aircraft.

The passengers boarding had been proceeded through the left front door. At 14:38:29 the CFA reported the passengers' boarding completion to the PIC. The PIC ordered to close the doors.

In the progress of the passengers boarding, the other aircraft (the flight, bound for Chelyabinsk) requested clearance for starting the engines up. The ATC officer asked to contact him later *«due to the traffic congestion»*. The crew of the RRJ-95B RA-89098 aircraft, apparently, noted this radio communication as at 14:38:41 the PIC uttered: *«Contact me due to the traffic congestion, they say… Chelyabinsk. Maybe they will clear us northbound after all»*[119].

Between 14:38:52 and 14:39:39 the PIC addressed to passengers.

By 14:40 all the entry doors and cargo compartment doors had been closed.

Prior to departure there had been 73 passengers and 5 crewmembers, 580 kg of the luggage and 292 kg (22 units) of cargo aboard the aircraft, of which:

– 292 kg of cargo, allocated on position # 13 in the front cargo compartment (maximum allowed load of 1945 kg);

– 580 kg of luggage on positions # 31 and # 32 (maximum allowed load of 2255 kg), allocated in the rear cargo compartment.

118 The crew previously discussed another SID – NERL 1C, which implies proceeding of the left turn after takeoff.
119 That is to say the PIC expressed hope that the SID would be changed.

There had been no dangerous cargo aboard the aircraft. The luggage was transported without containers.

As per the loadsheet the aircraft TOW was 43579 kg, the onboard fuel weight was 7240 kg, CG of 22.82 % MAC, which had not exceeded the established limit values (MTOW of 45880 kg, the CG range of 12.00 ÷ 34.30 % MAC).

Note: *At the activities on the engineering simulation of the flight that ended up with the accident, based on the trim analysis, the aircraft designer determined that the actual aircraft CG at the stage of the flight in DIRECT MODE had amounted to the 25 % MAC approximately. The engineering simulation outputs, outlined in Section 1.16.22 of the Report, had been obtained right for this CG value. To compare, the simulation scenarios, presented in Section 1.16.22.10 of the Report, had been replicated with the CG of 23 % MAC. The resulting differences in the aircraft pitch motion parameter values (the pitch attitudes and AOA, angle rate and pitch acceleration) do not exceed 2-3 %.*

At 14:42:48, after the ground personnel reported aircraft being ready for startup, the F/O contacted the Sheremetyevo Apron sector ATC officer: «Sheremetyevo Apron, good afternoon, Aeroflot 14-92, stand 107 Whiskey, information Bravo, request startup».

As there were many aircraft at line up the controller asked to contact him again in two minutes.

At 14:45:30, on the second request by the flight crew the ATC officer approved the engines startup.

The crew performed the entire BEFORE START section of the checklist (in the progress of the checklist section performance it had been confirmed that the doors were closed and armed) and started the engines up in a right-left sequence.

After the engines startup between 14:48:30 and 14:49:25, the crew checked the elevator and rudder and performed the entire BEFORE TAXI section of the checklist. At 14:49:29 the F/O reported ready for taxi to the Sheremetyevo Apron ATC officer.

The controller informed the crew on the route of taxi to RWY: «*To the left via BRAVO 1, BRAVO 2 to TWY 10».*

At 14:50 the crew initiated taxi. The taxi had been proceeded at the speeds of no more than 20 kt (37 km/h), which met the provisions of the FCOM item 04.25 (*«The recommended taxi speed not more than 30 kt»*). While taxiing the brakes and weather radar were checked with no comments.

At 14:51:05 the crew was handed off to the Sheremetyevo Ground sector ATC officer. After establishing contact the crew was instructed to taxi to holding point RWY 24C.

At 14:51:40 the crew started performance of the BEFORE TAKEOFF[120] Section of the checklist, where the reference speeds were called out as follows: V_1 – 129 kt (240 km/h), V_R – 135 kt (250 km/h), V_2 – 140 kt (260 km/h), as well as the takeoff configuration of FLAPS 2 (δsl = 24°, δfl = 16°), which was consistent with the FCOM provisions for the actual takeoff conditions. The stabilizer was set for takeoff at 2.2° to nose-up that had been generally in line with the estimated value, determined by the Table on the QRH A-43 (1) page.

At 14:54:14 the PIC instructed the F/O: *«Tell her taxiway 5 to transfer us to»*.

At 14:54:25, after the F/O's report on the aircraft at holding point, the crew was handed over to the Sheremetyevo Tower ATC (the C1 sector of the tower control unit).

At 14:56:10 the crew was cleared to line up at RWY 24C. At 14:56:25, on completion of the respective procedures the PIC ordered to do the second part of the BEFORE TAKEOFF Section of the checklist. The section was done in full.

At 14:57:20 the crew taxied to the RWY 24C lineup, where waited for the takeoff clearance for 5 minutes approximately.

The crew watched as well the movement of other aircraft and expressed concern about their large number, which, in its opinion was delaying the clearance for takeoff. The PIC at 14:57:34: *«Will it take off before us? Or is it crossing?»*, at 14:59:26: *«To lineup as well? For cripe's sake»*, at 14:59:31: *«And three minutes after it»*, at 14:59:50: *«The heavy's got kicked out»*, at 15:00:05 *«Now this is to take off, this is to land. And we will be cleared only then»*, at 15:01:02 *«It is just at 1000 feet»*.

At the lineup the crew was observing clutters at the weather radar (the PIC at 14:58:27: «*The clutter, can you see it (en rou…)*?»)[121], at that the PIC's ND scale was changing within 5 nm (9.3 km) and 20 nm (37 km).

Fig. 143 presents the flight data at takeoff and climb, the flight path and the crew's communication are given on Fig. 144.

[120] This section consists of two subsections. At that point the crew did the first subsection.
[121] The Interim Report incorrectly read that this utterance had been combined with the utterance: *«For cripe's sake…»*. Actually the sentence *«For cripe's sake…»* had been uttered at 14:58:58, but had been the first after the sentence «*The clutter, can you see it (illeg.)*».

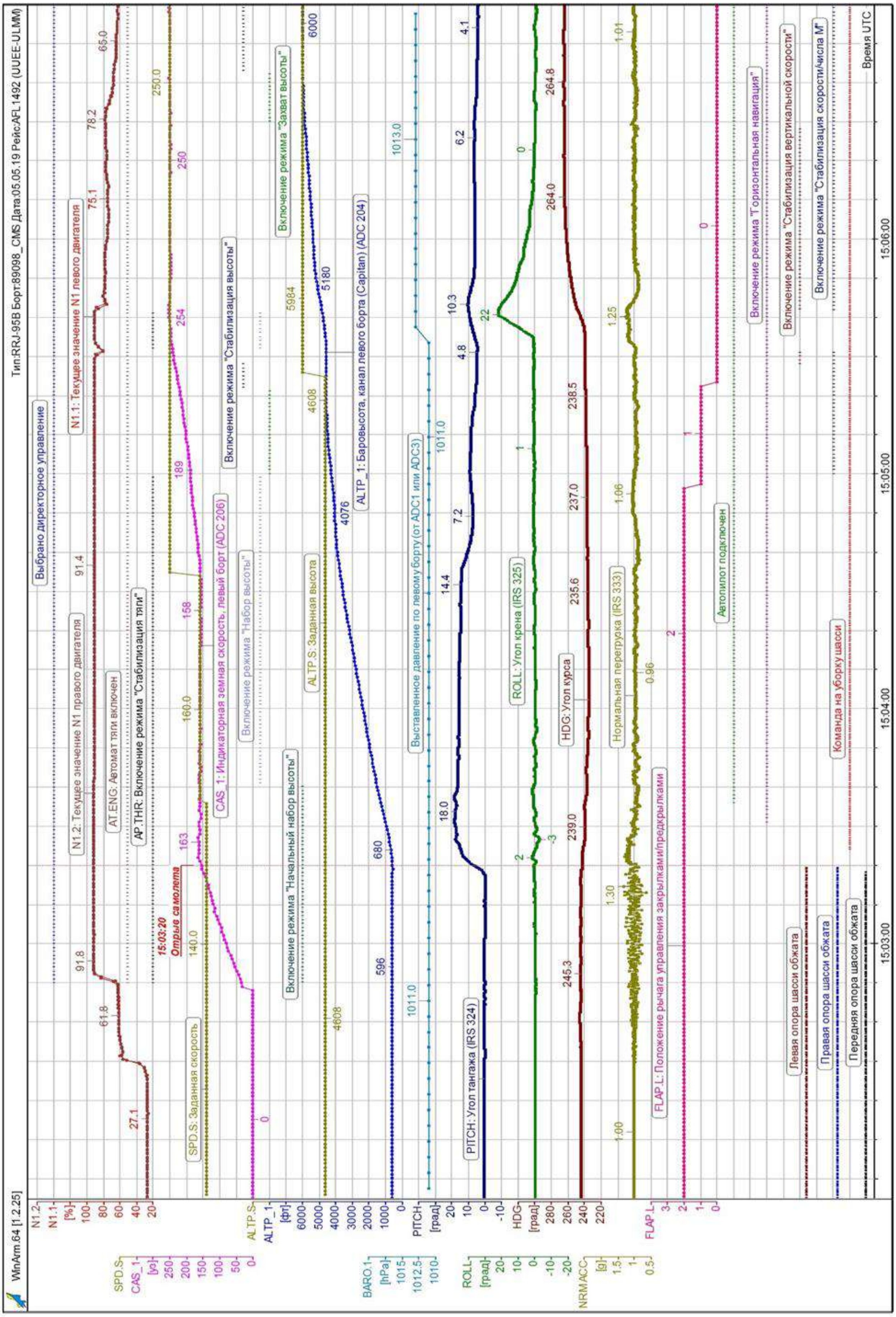


Fig. 143. The data of the RRJ-95B RA-89098 aircraft flight that ended up with the accident (at takeoff and climb)

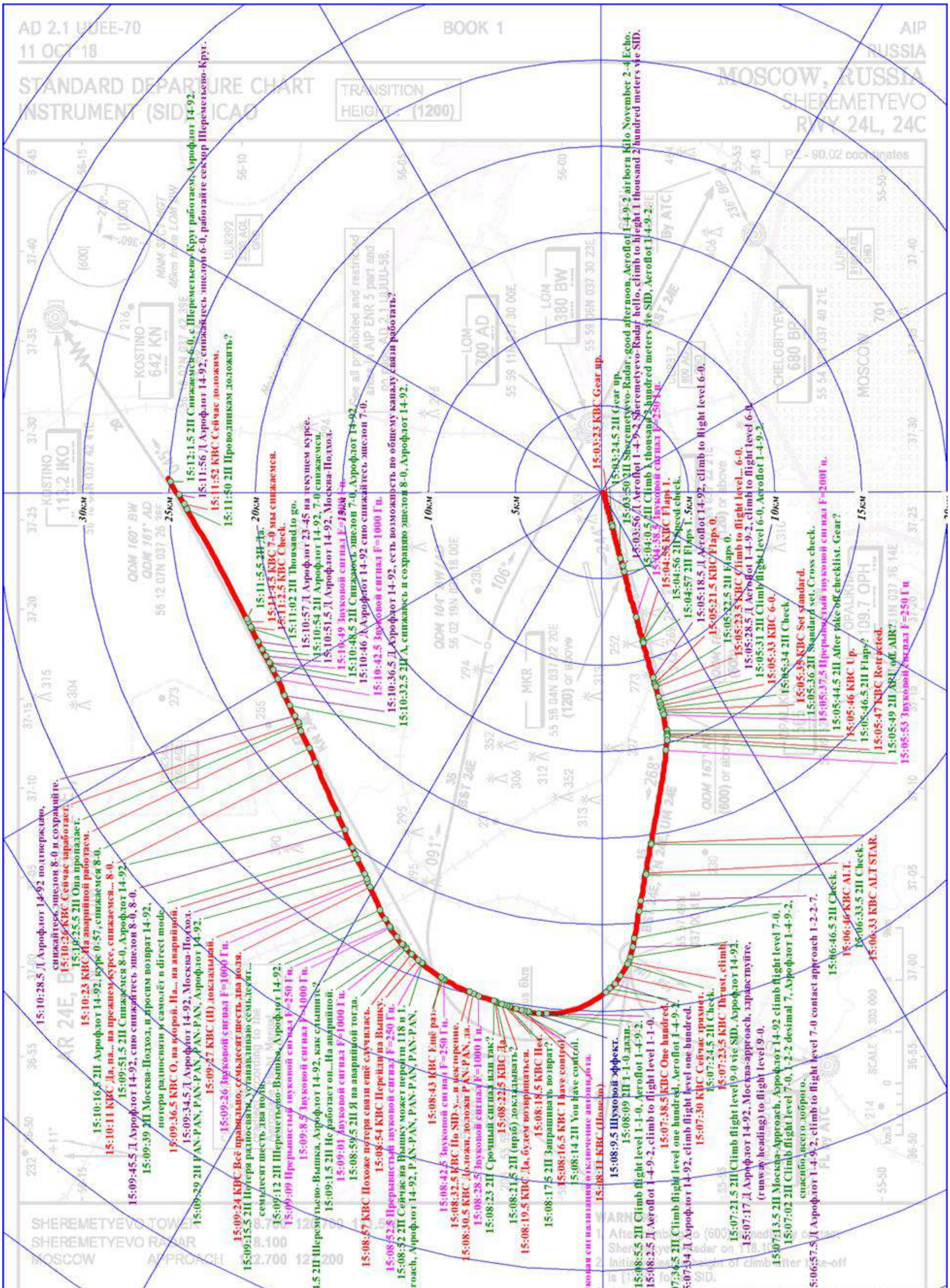


Fig. 144. The flight path of the RRJ-95B RA-89098 aircraft flight that ended up with the accident (at takeoff and climb)

At 15:02:23 the ATC officer relayed the information on the wind to the crew: 140° 4 m/s, gusts to 8 m/s and cleared takeoff from RWY 24C. The crew acknowledged clearance and initiated takeoff run.

At 15:02:49 at the speed of 30 kt by pressing the TO/GA pushbutton the PIC engaged the A/T, which is consistent with the FCOM item 04.57 (the respective THRUST and A/T green indication was displayed at FMA). The TL were automatically set to the NORMAL TAKEOFF mode (TLA – 48°, N_1 – 92 %). Concurrently with the A/T engagement the FD bars at the TO (takeoff) mode of the AFCS were activated.

Note: *Into the takeoff run the FD bars are not displayed, at the rotation when reaching the pitch attitude of 3˚, the pitch command bar starts to be displayed on PFD.*

In the progress of takeoff run the PIC's ND navigation scale amounted to 5 nm (9.25 km), of this to the F/O – 10 nm (18.5 km)

The liftoff occurred at the speed of 154 kt (285 km/h). After the *Positive climb* callout, ordered by the PIC, the F/O retracted landing gear.

At the true altitude of 35 ft. (11 m) at the AFCS lateral channel the TAKEOFF TRACK mode was automatically activated with the display of TO TRK on FMA and the appearance of the roll director bar on PFD with the subsequent automatic transition to LATERAL NAVIGATION mode at the true altitude of 400 ft. (122 m) with the display of LNAV on FMA.

At 15:03:36 on the QNH altitude of 1250 ft. (380 m) (the radio altitude of 690 ft. (210 m) and IAS of 160 kt (296 km/h) the PIC engaged A/P and then set the target speed of 160 kt. In the pitch channel the TAKEOFF/TO mode was engaged, whereas in the lateral channel – LATERAL NAVIGATION / LNAV.

At 15:03:41 at the QNH altitude of 1545 ft. (471 m) the CLIMB / CLB was activated in the pitch channel. The A/T was operated in the THRUST mode, at that the engines power rating was reduced (TLA – 31°, N_1 – 91 %). The climb was proceeded with the vertical speed of ≈ 3500 ft./min (≈ 18 m/s).

At 15:03:50 the F/O reported airborne to the Sheremetyevo Radar sector ATC officer.

At 15:03:54 the PIC's navigation display scale was zoomed from 5 nm (9.25 km) to 10 nm (18.5 km).

At 15:03:56 the Sheremetyevo Radar sector ATC officer instructed the crew to climb to the 1200 m QFE altitude as per the KN 24E SID.

At 15:04:10 the F/O's navigation display scale was zoomed to 20 nm (37 km).

At 15:04:33 the AFCS FMS SPEED CONTROL mode was activated, at that the target speed of 250 kt (463 km/h) was set. Into the continuing climb the A/P ensured the aircraft acceleration by reducing the flight path angle and the vertical speed accordingly.

At 15:04:56, after reaching the IAS of 185 kt (343 km/h) (it corresponds to the F speed, recommended to initiate the high-lift devices retraction to the intermediate position after takeoff), the crew initiated the high-lift devices retraction to the FLAPS 1 position (δsl = 18°, δfl = 3°).

At 15:05:00 the ALTITUDE CAPTURE / «ALT*» mode was engaged, as the airplane approached the H_{target} of 4608 ft. (1405 m), set prior to takeoff. The A/T transitioned to the SPEED/MACH mode.

Note: *Hereinafter the values of the target altitude, vertical speed, etc. are cited consistent with the FDR record. At that the sampling rate of one or the other recorded parameter physical value (the accuracy of the record or the weight of the low-order bit) is varied. For instance the target altitude values are recorded with the accuracy of 32 ft. and these of the target vertical speed – 93.75 ft./min. With that the crew has the option to select the value of the target altitude with the accuracy of 100 ft., of the vertical speed - as accurate as 100 ft./min. In other words at the record of 4608 ft. of the target altitude, indicated in the previous para, the crew had actually set the value of 4600 ft.*

At 15:05:18 the Sheremetyevo Radar sector ATC officer instructed to climb to FL60.

At 15:05:22 the aircraft established at the target altitude of 4608 ft. (1405 m), after that the ALTITUDE HOLD/ALT mode was engaged. Concurrently after reaching the IAS of 224 kt (415 km/h) (it is consistent with the Green Dot speed – this, recommended to initiate flaps retraction to the cruise position), the crew started the high-lift devices retraction to the FLAPS 0 position (δsl = 0°, δfl = 0°).

At 15:05:24 the target altitude was set to 5984 ft. (1824 m) and almost immediately after the AFCS VERTICAL SPEED/VS mode was engaged at the target vertical speed Vy = 0 m/s. The TL were retarded (down to 26°), as at this point the aircraft almost reached the target airspeed of 250 kt (463 km/h).

At 15:05:32 the crew engaged the CLIMB/CLB mode. The A/T transitioned to the THRUST mode and set the TLA of 29.4°, which corresponds to the engines CLIMB power rating.

At 15:05:35 the crew set 1013 hPa QNE.

At 15:05:42 the crew engaged the VERTICAL SPEED / VS mode and set the target vertical speed of 938 ft./min (4.8 m/s). Concurrently in the LATERAL NAVIGATION / LNAV mode the aircraft started the right turn to the heading of 268° as per the KN 24E SID (Fig. 145).

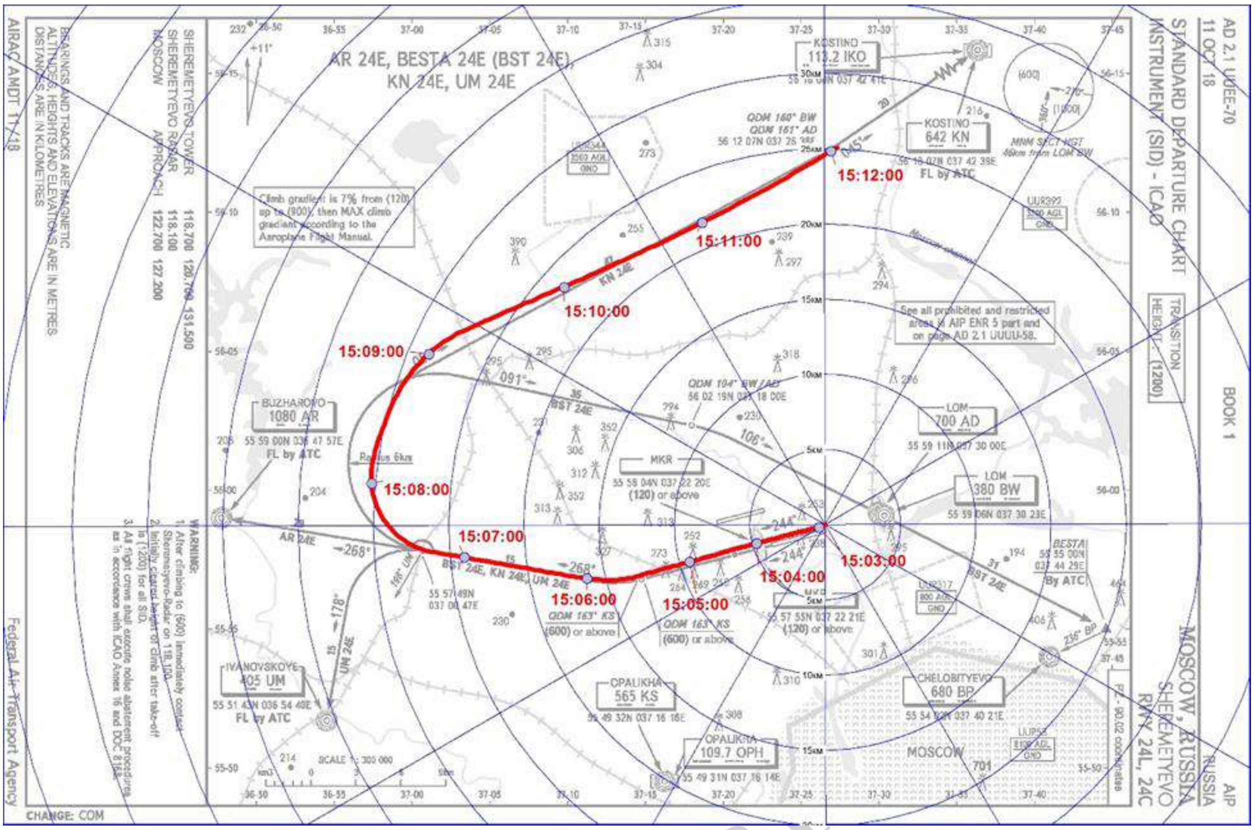


Fig. 145. The flight path, combined with the KN 24E SID

Between 15:05:44 and 15:05:53 the crew performed the entire AFTER TAKEOFF section of the checklist, no anomalies in the aircraft systems operation were called out.

Between 15:06:05 and 15:06:45 the PIC's ND scale was changing within 10 nm (18.5 km) – 20 nm (37 km) – 80 nm (148 km) – 10 nm (18.5 km) – 5 nm (9.3 km). At 15:06:26 the F/O's navigation display scale was set to 10 nm (18.5 km).

At 15:06:30 the ALTITUDE CAPTURE / ALT* mode was engaged and the aircraft established at the target altitude of ≈ 6000 ft. (1830 m), after that the ALTITUDE HOLD / ALT mode was engaged. The IAS was 250 kt (463 km/h).

At 15:06:57 the Sheremetyevo Radar ATC officer instructed to climb to FL70 and contact the Moscow Approach controller. The crew set the new target altitude of 7008 ft. (2136 m) and engaged the VERTICAL SPEED / VS mode. The target vertical speed was 938 ft./min (4.8 m/sec).

At 15:07:10 in the A/P lateral channel the HEADING / HDG was engaged, at that the target value was set to 327° (Fig. 146). The autopilot mode was changed by one of the flight crew (by the PIC's, most probably) without calling it out to the other flight crewmember. Up to that point the corresponding changes of the modes were called out by the PIC and acknowledged by the F/O.

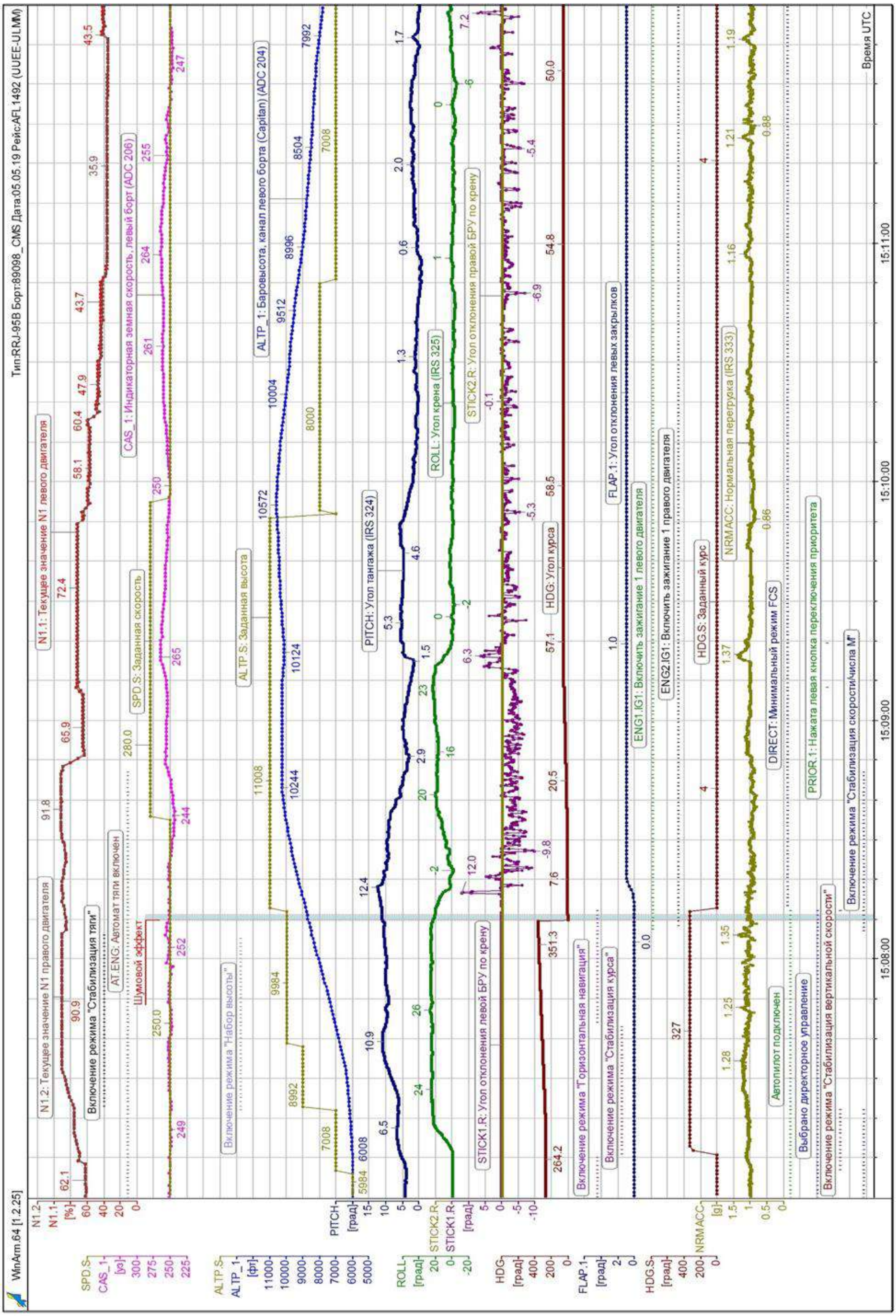


Fig. 146. The data of the RRJ-95B RA-89098 aircraft flight that ended up with the accident (the vertical grey line highlights the point of the exposure to atmospheric electricity)

As per the Vnukovo TDWR data[122] at that moment the aircraft was approaching the thunderstorm activity zone (Fig. 147) that moved from southwest to northeast with the speed of 14 – 15 m/s (Fig. 148 and Fig. 149). The transition to the target heading mode caused the aircraft to start turning to the right earlier than it is required by the KN 24E SID (Fig. 145). The crew did not request to avoid the thunderstorm activity zones. Section 1.18.1 of the Report reads the summary table of the avoidance requests by the aircraft, having departed before and after the SU-1492 flight. The ATC officers had not relayed the information on the avoidance requests by the other traffic to the RA-89098 aircraft flight crew.

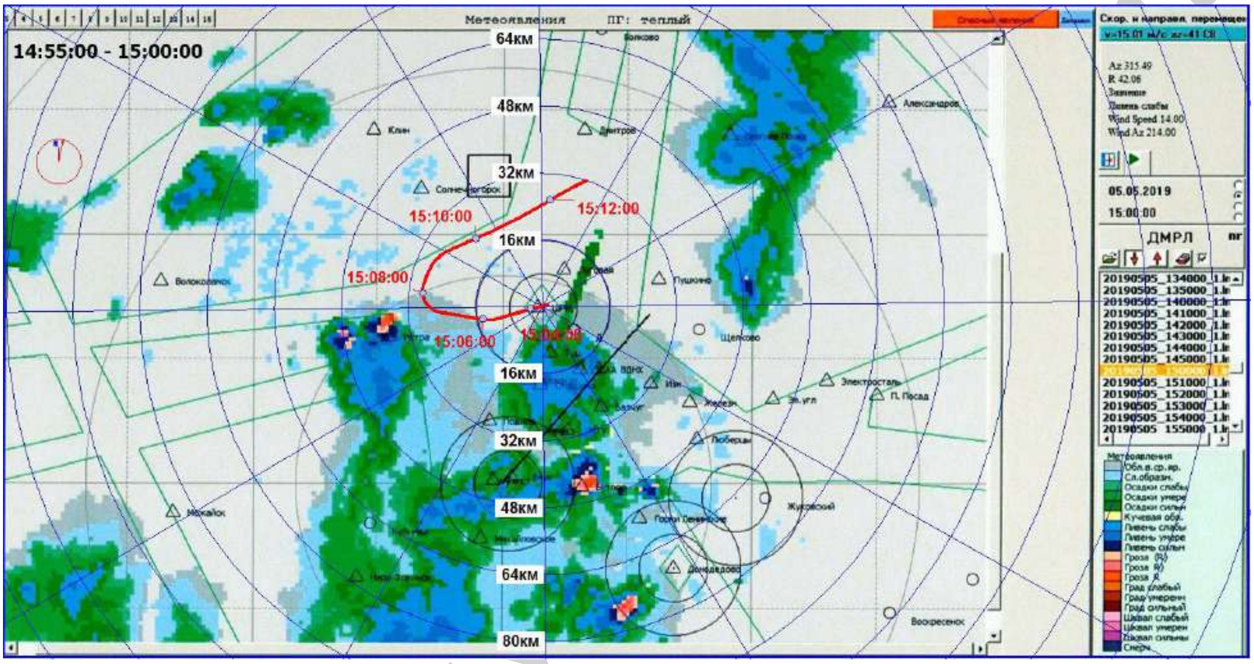


Fig. 147. The flight path, combined with the Vnukovo TDWR data over a period of time of 14:55 – 15:00

[122] Due to the features of the Vnukovo TDWR operation as for the given images only the time interval can be indicated, which they had been obtained for. The aircraft weather radar display image over these time intervals might have been different (see Section 1.16.1.16.12 of the Report as well).

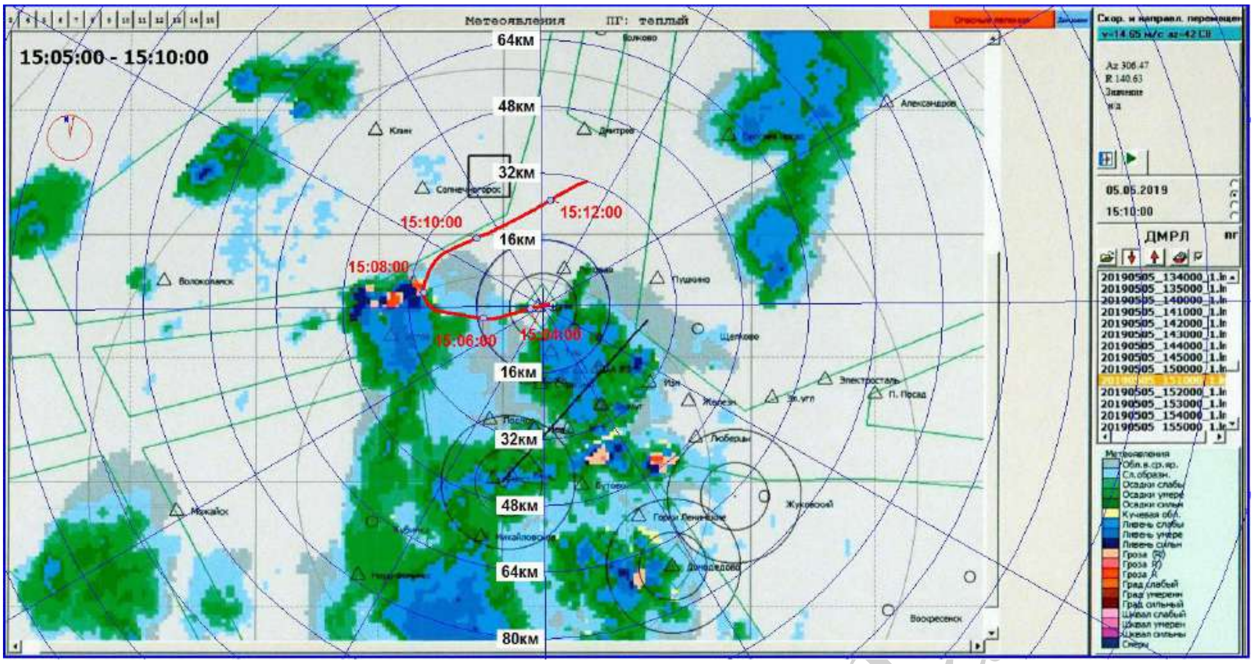


Fig. 148. The flight path, combined with the Vnukovo TDWR data over a period of time of 15:05 – 15:10

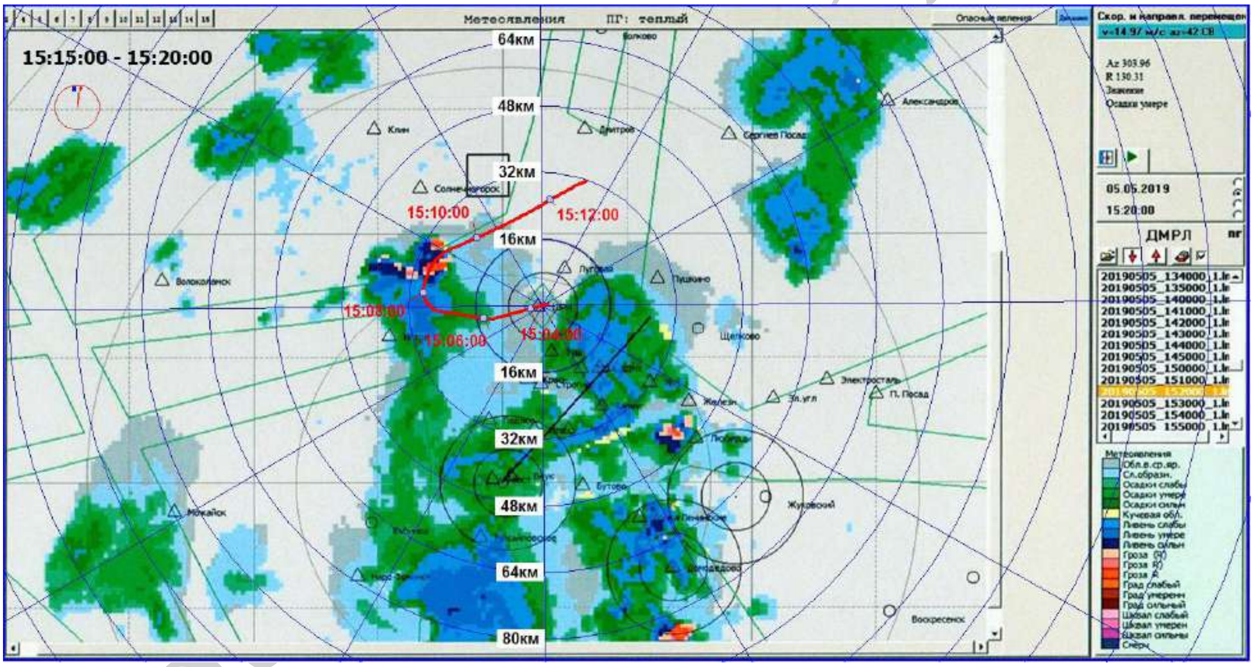


Fig. 149. The flight path, combined with the Vnukovo TDWR data over a period of time of 15:15 – 15:20

The flight crew contacted the Moscow Approach ATC officer at 15:07:13. The Approach ATC officer instructed the flight crew to climb to FL90. At 15:07:21 the flight crew set the new target altitude of 8992 ft. (2741 m) and engaged the CLIMB / CLB mode. The change of automatic flight mode was called out by the PIC and checked by the F/O.

Over the period of time of 15:07:30 – 15:07:33 the dialogue as follows is recorded in the crew: *«It is going to bump now»,* – F/O: *«Crap»,* – PIC: *«That's all right».*

At 15:07:34 the Approach ATC officer instructed to climb to FL100. At 15:07:39 the target altitude of 9984 ft. (3043 m) was set by the flight crew, at that the CLIMB/CLB mode was kept engaged in the pitch channel. The new target altitude was called out by the PIC, but not acknowledged by the F/O.

At 15:07:43 the guidance in a horizontal plane was once again switched to the LATERAL NAVIGATION/LNAV mode. By that time the aircraft was flown on heading of 317° in a turn with right bank of 24° at the IAS of 250 kt (463 km/h). The maximum cross-track deviation off the KN 24E SID amounted to 1.5 km (to the right off the assigned track).

At 15:08:03 the Approach ATC officer instructed to climb to FL110. After the acknowledgement by the F/O of this instruction, the CVR for 1.5 second, starting from 15:08:09.7, recorded a noise effect. Most probably, at that very point the aircraft encountered atmospheric electricity. The aircraft was then proceeding flight at the altitude of 8685 ft. (2647 m) QNE. Three seconds earlier, the FDR started recording discrete signals, indicative of the crew having activated the continuous ignition to both engines.

Note: ***FCOM, Section 1.04.60 «AFTER TAKEOFF»***

«…

Set ENG START to IGN/ON position, if severe turbulence or heavy rain is encountered».

At 15:08:11 the flight crew set the new values of target altitude of 11008 ft. (3355 m) and the rate of climb of 3281 ft./min (16.7 m/sec), along with the engagement of the VERTICAL SPEED/VS mode. The CVR has not recorded any callouts and their acknowledgment on the modes change.

At 15:08:12 the A/P disconnected, accompanied with the respective sound warning and the FBWCS reversion to DIRECT MODE with a *«DIRECT MODE. DIRECT MODE»* synthetic voice. The A/T kept being engaged. Following the noise effect concurrently with the A/P disconnection the emotional exclamation by one of the flight crew was recorded: *«Garn! »*. The aircraft was then flown in a right bank of about 20°, in climb, passing FL89 (2700 m).

Starting from 15:08:12, for about 15 sec. the FDR was incorrectly recording discrete signals and analog parameters values, the record of which is ensured by the EIU-100 Engine Interface Units. Concurrently the «EIU1 IS INVALID» and «EIU2 IS INVALID» discrete signals were recorded. The examination of EIUs was the evidence (see Section 1.16.2 of the Report) that at that stage there occurred the reboot of channels A to both EIUs, which was the reason for the FBWCS reversion to DIRECT MODE. At the aircraft certification, according to the Consolidated List of the RRJ-95B Aircraft Emergencies, the FBWCS reversion to DIRECT MODE was classified as «a major failure condition» (see Section 1.18.12 of the Report).

Following the reversion to DIRECT MODE the wing high-lift devices configuration was automatically set (as per design integrated logic) to the FLAPS ICE one (δsl = 0°, δfl = 1°). There were no flight crewmembers' comments on the aircraft configuration change recorded by CVR.

Note: ***The RRJ-95 aircraft FCOM item 1.08.27***

The switching to DIRECT MODE is accompanied with the «DIRECT MODE» synthetic voice and automatic setting of the wing high-lift devices to the FLAP ICE position.

Between 15:08:14 – 15:08:17.4 the communication as follows is recorded in the crew:

F/O: «You have control»;

PIC: «I have control».

From 15:08:16 the manual control from the left duty station was initiated. In approximately 4 sec from the A/P disconnect up to the PIC's interference in the control, the right bank decreased down to 13°, the pitch slightly increased (from 11° to 12° to nose-up).

The first control input was exercised by the PIC in the roll channel, the sidestick was deflected by 11.7° to the left (more than half of the travel), after that it was a sidestick forward input by 6.8°, which is equivalent to the sidestick half travel to nose-down.

At 15:08:17.4 the F/O asked: *«Shall we request a return? »*, to which the PIC replied: *«No»*. Still in a second the PIC changed his mind and communicated: *«Yes, we will return»*.

At 15:08:30, following a short talk in the crew the PIC commanded the F/O: *«Report, report PAN–PAN, yes»*.

At 15:08:32 the F/O attempted to report to the Approach controller: *« PAN–PAN, PAN–PAN, PAN–PAN, Aeroflot 14-92, request vectoring, return»*. This request was relayed at the operating frequency with the use of VDR 1 (this VDR had been used for communication from the beginning of the flight)[123]. This request was not recorded by the ATC recorder. At 15:08:44 the F/O made the second unsuccessful attempt to contact the ATC officer at the operating frequency with the use of VDR 1.

Note: *Prior to the in-flight emergency onset the crew communicated in English with the ATC, after that did it in Russian.*

The aircraft was then proceeding the right turn as per the KN 24E SID and climbed. At 15:08:47 with the TL override the A/T was disengaged.

After the second unsuccessful attempt to contact the Approach ATC officer the CVR recorded the command by the PIC: *«Switch to Tower»* – and in a second: *«It looks like the radio has been lost as well»*. The F/O replied: *«I am on the emergency [frequency] then»*.

At 15:09:04 on the emergency frequency with the use of VDR 2 the F/O relayed: *«Sheremetyevo Tower, Aeroflot 14-92, how you read? »*. This utterance was recorded by the ATC recorder. The response followed by the Sheremetyevo Approach ATC officer at his operating frequency (122.7 MHz): *«AFL 1492, climb to FL130, contact Moscow-approach, 127.2[124]»*. This response is not audible at the CVR, as this frequency had not been set on the VDR 2 and 3, which had remained serviceable.

At 15:09:12 the F/O once again contacted the Sheremetyevo Tower ATC officer on the emergency frequency with the use of VDR 2. This communication has been recorded by the ATC recorder as well. The contact back had been again by the Approach ATC officer, who repeated his instruction on the operating frequency: *«AFL 1492, climb to FL130, contact Moscow-approach, 127, and 2»*. This utterance is not recorded aboard either. Further on the Sheremetyevo Approach controller tried to call the flight crew twice more on the operating frequency. These requests have not been recorded by CVR.

[123] See Section 1.18.26 of the Report as well.
[124] The operating frequency to the other Approach sector (the area of responsibility from FL130).

At 15:09:17 the aircraft was levelled off the right turn to a heading of about 60° (practically to the assigned track as per the KN 24E SID).

At 15:09:32, following the discussion on the occurrence of the radio loss, the crew set the 7600 squawk code (radio loss). Meanwhile the F/O made another attempt to establish radio contact on the emergency frequency with the use of VDR 2: *« PAN–PAN, PAN–PAN, PAN–PAN, Aeroflot 14-92»*. To this request the crew was replied by the Approach controller on the emergency frequency: *«Aeroflot 14-92, Moscow Approach»*, – to which the PIC responded: *«Oh, on the second. On... on the emergency»*.

Note: *1. Hereinafter, unless otherwise stated, the radio communication was conducted on the emergency frequency with the use of VDR 2.*

2. As per FAR-136 item 233 the radio contact is considered lost if within 5 minutes with all available radio communication channels the crew or the ATM (ATC) authority does not contact back to the repeated calls on each of the channels. Actually, as far as the flight that ended up with the accident is concerned, the radio contact had been lost less than 5 minutes. As the crew assessed the situation as the radio contact loss with the setting of the subject transponder code, this is the term used throughout the Report, subject to this disclaimer.

At 15:09:39, after the radio communication was resumed the F/O reported to the Approach controller: *«Moscow Approach, and request return, 14-92, radio lost and airplane in DIRECT MODE»*. The ATC officer instructed to descend to FL80. The maximum altitude the aircraft reached amounted to 10600 ft. (3230 m) QNE. The crew replied: *«Descending 8-0, Aeroflot 14-92»*. The ATC officer confirmed the clearance to descend with the proceeding on the present heading.

At 15:09:52 the crew set the target altitude of 8000 ft. (2438 m), then deactivated the FMS speed control mode, set the target airspeed of 250 kt (463 km/h) and transitioned the aircraft to descent. The change of the target parameters and operational modes values had not been called out by the crew.

At 15:10:17 the F/O reported to ATC officer: *«Aeroflot 14-92, heading 0-57, descending 8-0»*. The ATC officer replied: *«Aeroflot 14-92, affirm, descend flight level 8-0 and maintain»*. The further flight until the glideslope interception was carried out by vectoring. The aircraft flight path after the crew had made the decision to return, is given on Fig. 150.

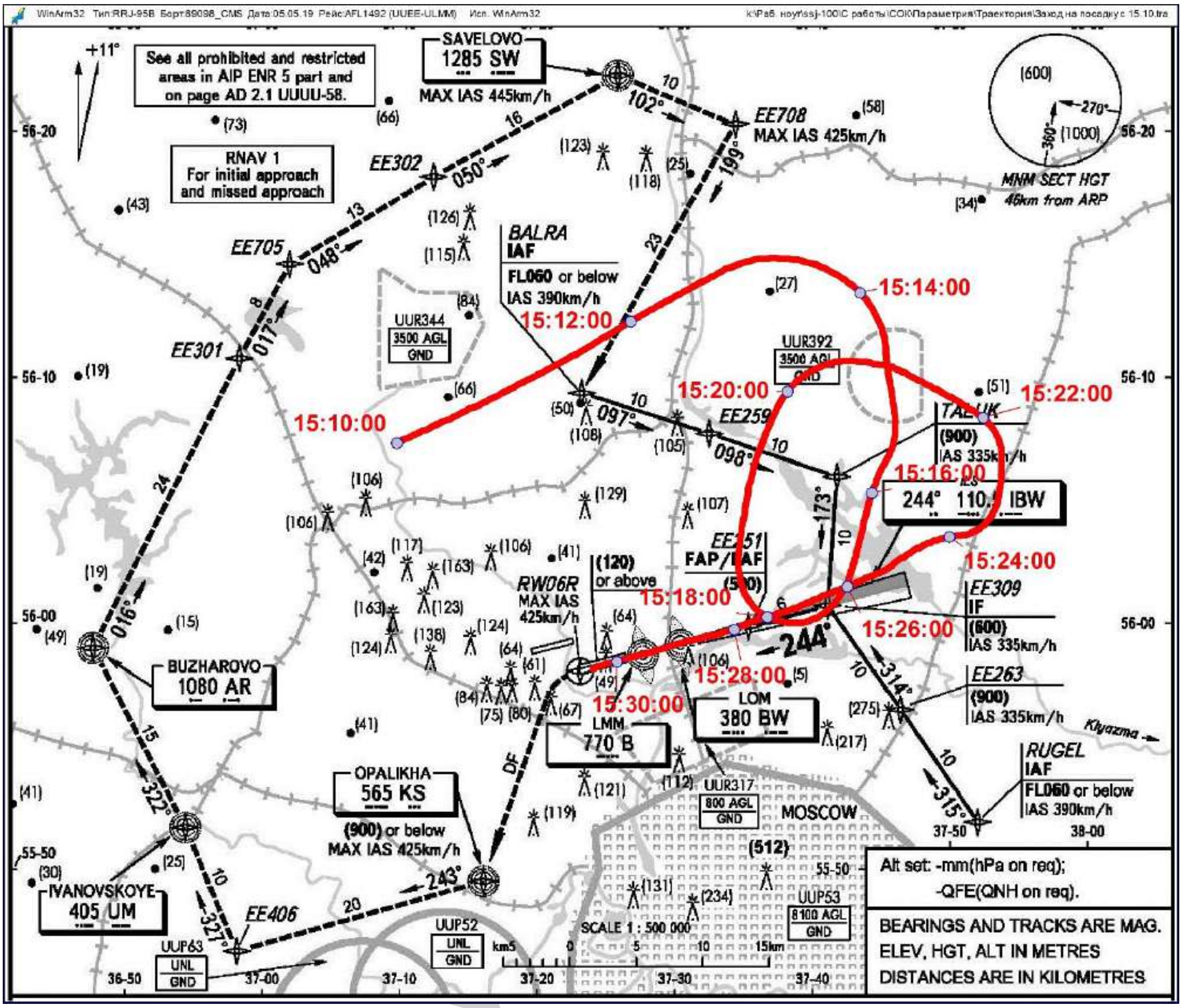


Fig. 150. The flight path, combined with the STAR

Starting from 15:10:23 the conversation as follows was held in the crew:

PIC: «Operate on the emergency».

F/O: «It is interrupted».

PIC: «It will start functioning now».

F/O: «Here it is, fine».

At 15:10:36 the ATC officer requested: *«Aeroflot 14-92, is it possible to contact on the general communication channel? ».* The PIC attempted to respond with the use of VDR 1 (it is at which the operating frequency was set). As this VDR was unserviceable, the response is not recorded on the ATC recorder. The crew did not attempt to establish radio contact with the use of VDR 2, but on the operating frequency. The VDR 3 had not been used by the crew (see Section 1.18.26 of the Report as well).

At 15:10:46 the controller on the emergency frequency instructed: *«Aeroflot 14-92, descend now flight level 7-0».* The reply by the F/O: *«Descending flight level 7-0, Aeroflot 14-92»* – was transmitted with the use of VDR 1 and had not been recorded by the ATC recorder.

At 15:10:51 the ATC officer contacted once again: *«Aeroflot 14-92, Moscow Approach»*. The response by the F/O on the emergency frequency with the use of VDR 2: *«Aeroflot 14-92, 7-0 descending»* – has been recorded by the ATC recorder.

At 15:10:51 the target altitude was reset by the crew to the value of 7008 ft. (2136 m).

At 15:11:50 the F/O asked the PIC: *«Shall I report to flight attendants? »*, to which the PIC replied: *«We will report now»*.

At 15:11:56 the Approach controller instructed: *«Aeroflot 14-92, descend flight level 6-0, contact Sheremetyevo Radar sector*». The crew confirmed the instruction: *«Descending 6-0, contacting Sheremetyevo Radar, Aeroflot 14-92»*. At 15:12:01 the target altitude was set to the value of 5984 ft. (1824 m).

At 15:12:14, to the request by the F/O: *«Shall we proceed on this, on the emergency? »*, the PIC answered affirmative.

At 15:12:23 and 15:12:28 the F/O on the emergency frequency with the use of VDR 2 called the Sheremetyevo Radar controller. These calls have been recorded by the ATC recorder, still at that stage the ATC officer did not respond due to the active radio communication with the other aircraft on the operating frequency.

At 15:12:32 the PIC via aircraft intercom explained to the CFA that the aircraft is returning, at that pointed out: *«It is not an emergency, nothing, just returning»* – and specified: «…*problems with radio contact and control*». The flight attendant replied: *«… got it, due to technical issues»*.

At 15:12:40 the Sheremetyevo Radar controller contacted the crew. After the report by the F/O: *«… flight level 60»*, – the ATC officer instructed: *«…to the right heading 140, descend 900 meters, QFE 9-8-9, 24 left active»*. The crew confirmed this instruction.

At 15:12:47 the target heading of 140° was set and the PIC entered the aircraft to the right turn (Fig. 151). The turn was proceeded with the variable roll of between 13° and 22°.

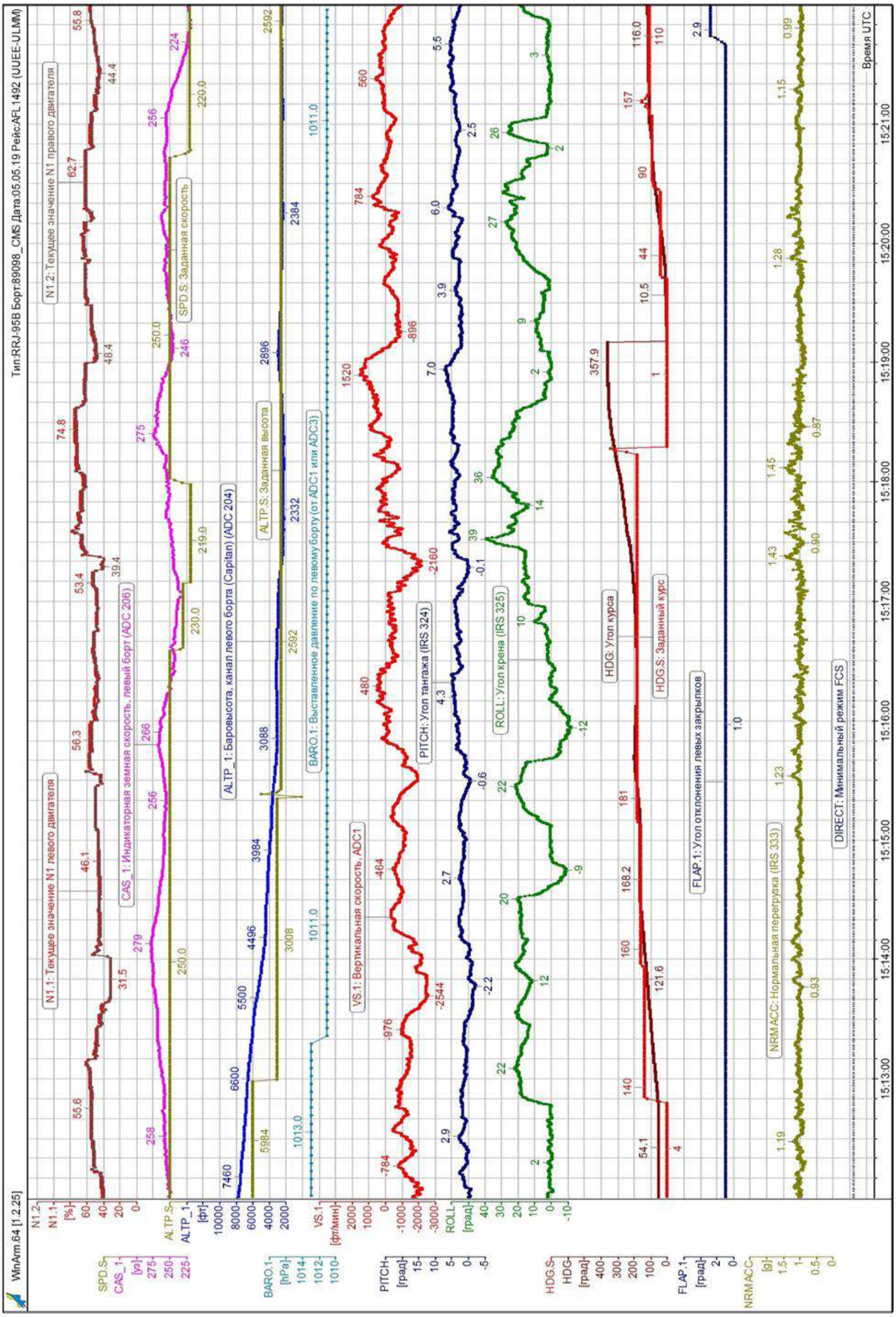


Fig. 151. The data of the RRJ-95B RA-89098 aircraft flight that ended up with the accident (the proceeding of «the orbit»)

At 15:13:00 the crew set the target altitude of 3008 ft. (917 m), that is unadjusted for the aerodrome elevation.

At 15:13:05 the conversation as follows was recorded in the crew:

F/O: *«So, we were cleared to descend to 900»*.

PIC: *«Descending 900 meters»*.

Shortly after the QNH of 1011 hPa was set.

At 15:13:11 the PIC ordered the F/O to do the F/CTL DIRECT MODE QRH section (it is referred to the Abnormal Procedures, see Section 1.18.4 of the Report). This procedure is not among memory items, that is it should be done by the crew on the READ – DO principle. The procedure is to be read by the PNF.

At 15:13:42 the F/O began reading the AUTO FLT AP OFF QRH section, which covers the emergency procedures rather than the abnormal ones. The actions as per this section consist of two items (AP BUTTON ON FCP - PRESS; IF UNSUCCESSFUL – OPERATE AIRPLANE MANUALLY). The F/O had read and done the first item, the A/P had not been re-engaged (consistent with the design integrated logic), at that the warning sound signal had been triggered.

At 15:13:51 the ATC officer asked the crew: *«…will any assistance be required? »* and instructed to turn to a heading of 160°. The crew set the target heading of 160° and replied: *«No, so far everything is fine, as assigned».* To the controller's clarifying request the crew responded that there were the radio communication issues and the automatic flight control was lost.

The radio contact session lasted till 15:14:11. On the completion of the session the F/O started reading the AUTO FLT AP OFF QRH section again. This time the A/P was not reengaged again. After the utterance by the F/O: *«… Auto flight autopilot off checklist completed»* the PIC corrected the F/O and once again requested reading of the F/CTL DIRECT MODE Section.

At 15:14:36 the aircraft was proceeded to the heading of ≈ 170°.

At 15:15:05 the ATC officer instructed the crew to turn to the right on the heading 180° and descend to the QFE altitude of 600 m.

At 15:15:10 the target heading was set to 181°.

At 15:15:27 the target altitude was reset to 2592 ft. (790 m)[125]. Till the FDR record stop this value was not changed.

At 15:15:34 the controller cleared ILS Yankee approach, runway 24 left. After acknowledgement of the clearance the F/O started reading the F/CTL DIRECT MODE QRH procedure, at that it had been spoken out inter alia: *«… Autothrottle do not use, maneuver with care. … Trim – manually. …Speed brake - use not more than 1/2. … for landing – use Flaps 3. TAWS,*

[125] The QNH altitude, approximately corresponding to the 600 m QFE altitude, specified by the ATC officer.

landing gear, Flaps 3 on. Approach speed, V reference plus 10. Landing distance – multiply by 1.34. … Speed brake - set manually FULL at landing. Go-around thrust levers – set manually NTO».

At 15:16:54 the controller instructed: *«… continue to the right heading 210 to intercept localizer …».*

At 15:17:29 the PIC spoke out to the F/O: «*We should proceed by circuit. We are not ready for approach».* At 15:17:39 the F/O, ordered by the PIC, reported to the ATC officer having been not ready for approach and requested «*orbit»,* but then corrected himself – *«by circuit»,* to which the controller responded: *«…heading 360 to the right».*

At 15:18:53 the PIC attempted to contact the ATC officer himself: *«Aeroflot 14-92, a holding spot over Kilo November, if possible».* The analysis of the ATC recorder content revealed that this utterance, transmitted on the emergency frequency, is audible[126], still is heavily «crammed» with the radio communication on the operating frequency with the other traffic. Hence, most probably, the ATC officer did not hear this request and did not respond to it. The PIC never mentioned this issue again.

At proceeding the flight at the QFE altitude of 600 m the PIC was not able to maintain altitude with the required precision. At the right turns with the bank angles up to 40° the deviations off the target altitude exceeded ± 200 ft. (60 m), which caused the repeated trigger of the altitude alerting system (the deviation from target altitude sound alert). The PIC was aware of this fact and spoke it out, for instance, at 15:22:53: *«What's wrong. Plus-minus 200 feet».*

At 15:19:11 the F/O asked the PIC whether it was necessary to do the OVERWEIGHT LANDING QRH section (it refers to the Emergency Procedures, see Section 1.18.5 of the Report). The PIC responded affirmative. The aircraft weight amounted to about 42600 kg, which exceeded the maximum allowed landing weight for 1600 kg.

Note: *The analysis of the CVR record was the evidence that the flight crew did not look into the option of fuel burnoff [127] to reduce the landing weight.*

To obtain the maximum available thrust for the event of go-around the flight crew selected the L AIR and R AIR switches OFF. Additionally the F/O spoke out the maximum vertical speed at touchdown of 360 ft./min (1.8 m/s). At the performance of landing as assigned (compliant to the Normal Procedures) the vertical speed at touchdown, recommended by FCOM is 150 – 200 ft./min (0.76 – 1 m/s).

[126] The Interim Report incorrectly stated that this utterance had not been recorded by the ATC recorder.
[127] The RRJ-95 is a short-haul aircraft with the relatively short flight segments. It does not feature the fuel dump. At that the FCOM stipulates landing with MTOW.

Note: ***the RRJ-95 FCOM, Standard Operating Procedures, section 04-80 LANDING:*** *«At manual landing the vertical speed at touchdown should be of 150 – 200 ft./min (0.76 – 1 m/s)».*

At 15:19:38 the ATC officer instructed the flight crew to initiate right turn to a heading of 090°, requesting as well the report on the readiness to initiate approach: *«report when ready for approach».* The crew initiated executing a command on the heading change (at that initially the target heading had been set to 44°, the value of 90° was set at 15:20:32) and relayed: *«…will report later, Aeroflot 14-92».* However this response by the crew had not been transmitted as the F/O had not pressed the radio PTT button (see Section 1.18.26 of the Report as well).

At 15:19:50 the PIC ordered the F/O to start the APU and at 15:19:56 to activate the route to the TALUK waypoint at FMS.

At 15:20:10 the ATC officer contacted the crew once again with the request on the presumed point of time when ready for approach, the F/O relayed afterwards: *«Will report, Aeroflot 14-92».*

At 15:20:37 the PIC ordered the F/O to set the target speed of 220 kt (407 km/H). In 9 sec. the IAS started to gradually decrease to the target value.

At 15:20:37 the APU air intake flap was detected opened and in 3 sec. the APU rotor speed started to increase.

Fig. 152 presents the path of the final leg of the flight with overlapping of the crew communication.

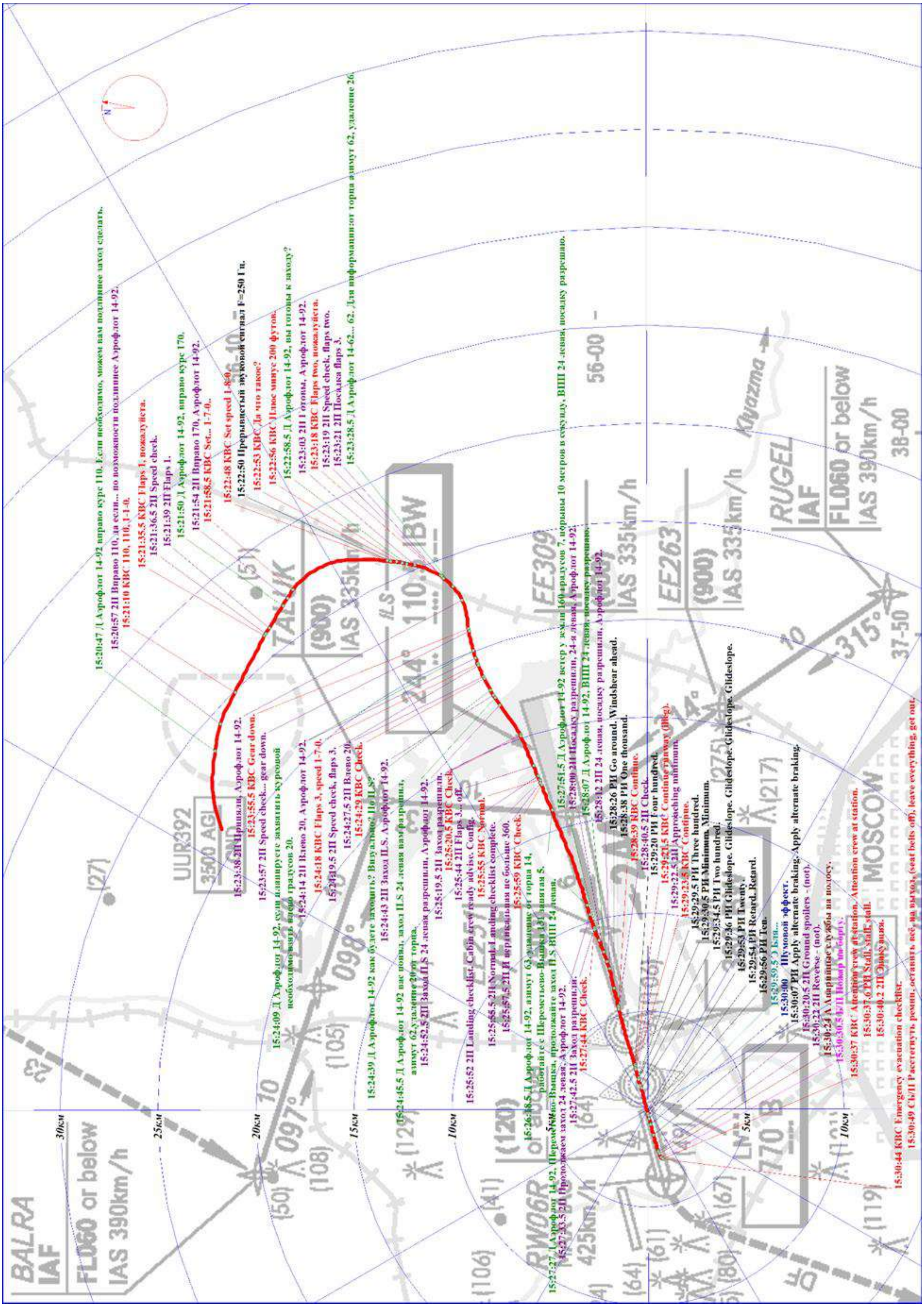


Fig. 152. The path of the RRJ-95B RA-89098 flight that ended up with the accident at the final leg

At 15:20:47 the ATC officer instructed to make the right turn to a heading 110°, along with the information on the availability to ensure a longer approach path. The PIC immediately proceeded to the execution of the controller's command (at that the target heading was set to the value of 110° not earlier than at 15:21:20, after establishing on that heading) and instructed the F/O to coordinate a longer approach, which was done.

At 15:21:18 the F/O reported the completion of the APU start to the PIC.

At 15:21:38 at the IAS of 225 kt (415 km/h) the flaps extension was initiated to the FLAPS 1 position (δsl = 18°, δfl = 3°). At 15:22:25 the stabilizer was manually reset to the 3.1° position to nose-up[128].

At 15:21:50 the ATC officer instructed the crew to proceed the right turn to the heading of 170°. The crew reset the heading selector to the indicated value and initiated the turn.[129].

By 15:22:40 the aircraft had been tracked to the heading of ~ 175°, still in 5-6 sec. continued the right turn with a variable roll (between 5° and 20°). There were no instructions by the ATC officer to continue the turn, the controller did not draw the crew's attention to the proceeding of the turn without being advised.

At 15:22:48 the PIC ordered the F/O to set the target speed value of 180 kt (333 km/h), which was done by the F/O (Fig. 153).

[128] In DIRECT MODE the automatic trim function in pitch channel is disabled. The flight crew is to trim the aircraft manually. The mentioned stabilizer resetting was the first one from the point of the reversion to DIRECT MODE.
[129] The target heading value remained unchanged until the FDR record stop.

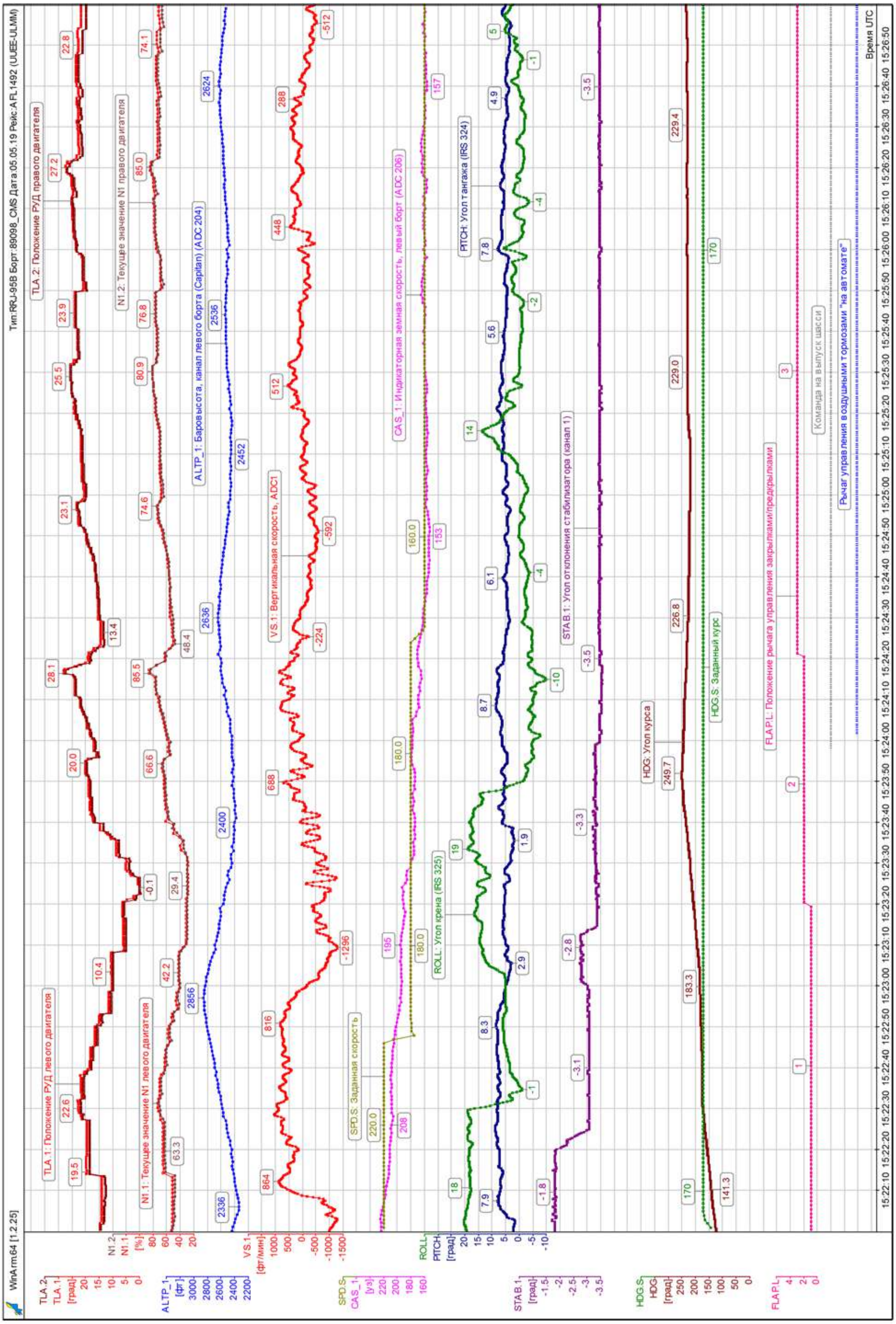


Fig. 153. The data of the RRJ-95B RA-89098 aircraft flight that ended up with the accident (established on final)

Upon the ATC officer's request at 15:22:59 on the flight crew's readiness to initiate approach the F/O at 15:23:03, ordered by the PIC, reported having been ready to the controller.

At 15:23:00 the stabilizer was reset from the 3.1° position to nose-up to the 2,8° to nose-up and later, at 15:23:14, to the 3.4° position to nose-up.

At 15:23:07 the F/O called out the completion of the OVERWEIGHT LANDING QRH section.

At 15:23:19 at the IAS of 190 kt (350 km/h) the flaps extension was initiated to the FLAPS 2 position (δsl = 24°, δfl = 16°).

At 15:23:29 the ATC officer informed the flight crew on the current aircraft position: *«… for information: from the threshold azimuth 62, distance 26».* The flight crew copied this information.

At 15:23:58 at the IAS of 178 kt (330 km/h) the crew initiated the landing gear extension, which is consistent with the FCOM provisions. Concurrently the stabilizer deflection was increased up to 3.5° to nose-up. Further on till the end of the flight the stabilizer position was not actually changed, one short press of the stab trim switches to nose-up at the glideslope descent is recorded.

Note: *Similarly for RA-89098 and the other RRJ-95 aircraft, the recorded horizontal stabilizer position is slightly altered at the elevator deflection. At that, the recorded changes of the stabilizer position are always in antiphase to the deflection of the elevator, and the more is the elevator deflection (so is the hinge moment), the more is the change in the recorded value of the stabilizer deflection. This is due to the features of the stabilizer position sensors installation location and their linkage flexibility. This is not the case of the actual further deflection of the stabilizer. For instance Fig. 154 presents the comparison of the data at the landing into the flight that ended up with the accident and into the flight of the RA-89046 aircraft of September 5, 2015, into which the landing was carried out in DIRECT MODE as well, and the pilot exercised significant alternating inputs of the sidestick at flare. The Figure is the evidence that the behavior (nature) of the stabilizer deflection record is absolutely identical. It is also worth noting that the elevator setting rate when the actuators reach the limit (that is, the maximum possible elevator deflection rate) are almost the same into both flights.*

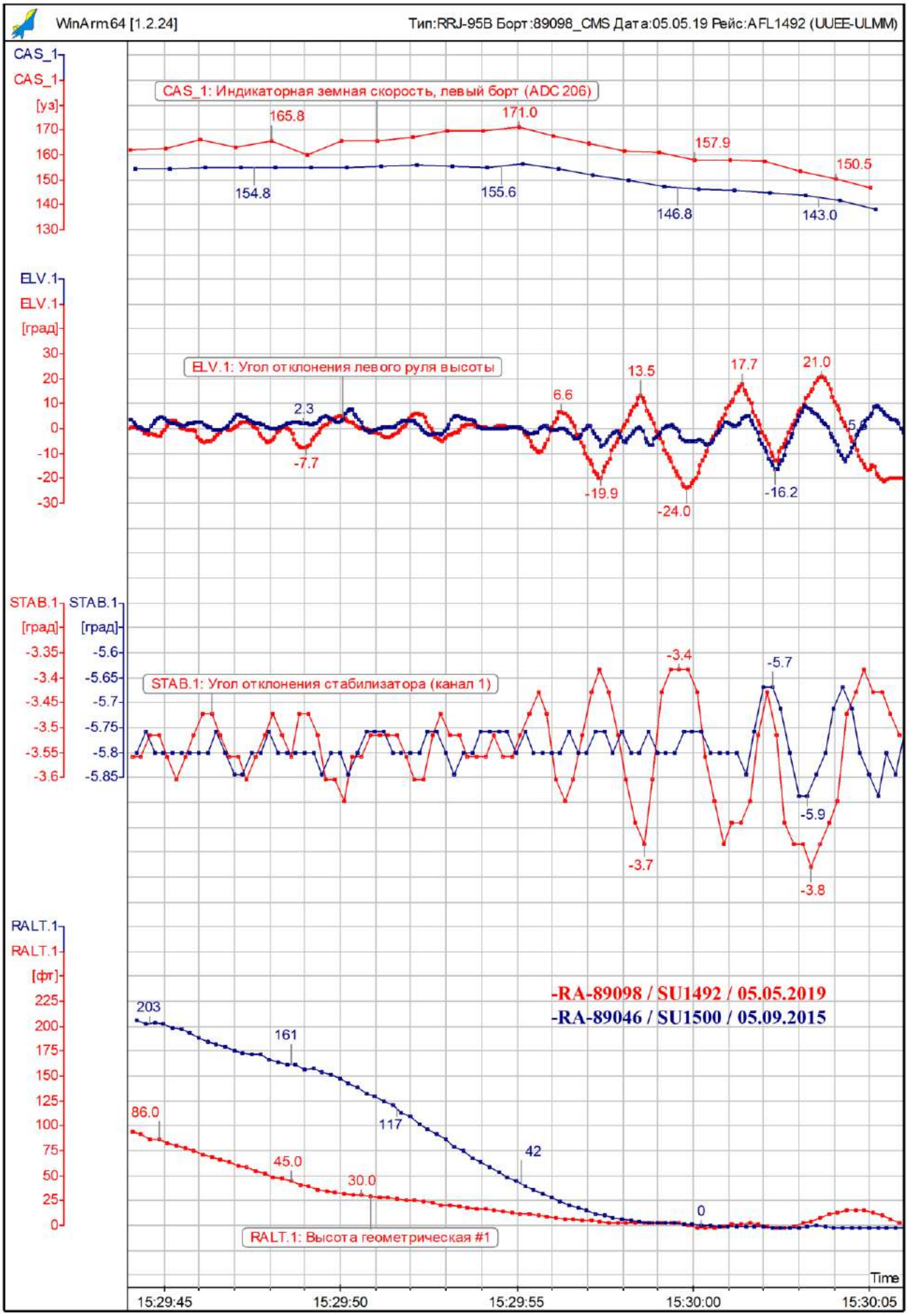


Fig. 154. The comparison of the stabilizer position records at the significant deflection of the elevator

At 15:24:02 the flight crew set the SPEED BRAKE handle to the GND SPLRS ARMED position, which – at the FBWCS NORMAL MODE – ensures the automatic deployment of the speedbrakes and ground spoilers at the landing after touchdown. At the FBWCS in DIRECT MODE the automatic deployment is disabled. In manual mode only the ground spoilers can be deployed, the deployment of the speedbrakes is interlocked. The operational documentation integrates this information, including the respective QRH procedure (see Section 1.18.4 of the Report).

Note: *According to the flight crewmembers' explanation this action was taken by them to prevent the trigger of the non-landing configuration alert at the performance of the respective check, provided for by the SOP at the glideslope descent before passing minimum stabilization height. The signal of the SPEED BRAKE handle position is one of the criteria of the check, at that there are no differences as for the FBWCS modes through the check algorithms. The investigation team notes that at the FBWCS in DIRECT MODE the necessity of setting the SPEED BRAKE handle in the GND SPLRS ARMED position may reduce the flight crew's situational awareness and create an impression on the possibility of the automatic deployment of the speedbrakes (the spoilers and speedbrakes), all the more so because the deployment of the kind occurs in every flight and the flight crews get used to it.*

After the turn to the heading, close to the landing one, the aircraft was flown significantly to the right off the extended RWY centerline, which the ATC officer drew the flight crew's attention to at 15:24:09: *«Aeroflot 14-92, if you are planning to capture the localizer, you should proceed to the left for about 20 degrees»,* the crew copied this information. The left additional turn was proceeded with the roll up to 10°.

At 15:24:20 at the IAS of 170 kt (315 km/h) the crew initiated the flaps extension to the FLAPS 3 position ($\delta sl = 24°$, $\delta fl = 25°$).

On the controller's request at 15:24:38 on the type of approach the crew relayed that it would be the ILS one (according to QRH in DIRECT MODE the ILS approach is only ensured by ILS raw data, the automatic and FD approaches are disabled).

Note: *As communicated by the aircraft designer, the FBWCS DIRECT MODE does not integrate the FLIGHT DIRECTOR function. The FLIGHT DIRECTOR function is attributable to AFCS, which, together with EFIS, ensures the display of the pitch and roll director bars for the processing of the AFCS command signals at the manual operation. The AFCS command signals are generated in* *the CEH and transmitted to the FBWCS PFCU to be then processed by the FCS. The AFCS and PFCU processors generate their command signals based on the data by the same systems (ADS, INS ...), the failure of which results in the concurrent failure of the AFCS command signals processing and the FBWCS reversion to DIRECT MODE. Given that the AFCS functionality is inoperative in DIRECT MODE, then, accordingly, the director bars display function is disabled either.*

The aircraft entered the localizer linear zone at about 15:24:40, the bar (repeater) of the deviation off the localizer equisignal zone started moving to the center of the instrument. The aircraft distance of the RWY 24L entry threshold was equal to ~ 22.5 km.

At 15:24:46 the Radar ATC officer cleared the approach to the flight crew: *«Aeroflot 14-92 … ILS approach 24 left cleared to you, azimuth 62, distance 20 off the threshold»*. The crew copied this information.

At about 15:25:40 at the distance of ~ 18.7 km of the RWY 24L entry threshold the aircraft entered the glideslope linear zone. The flight was proceeded at the average altitude of about 600 m above the RWY level (with the variations within 550 and 630 m). Compliant to the established approach pattern the altitude of the glideslope capture is 500 m QFE (Fig. 29).

By 15:25:57 the flight crew completed the LANDING section of the checklist that was done in full. The flight crew did not communicate any additional information to the cabin crew on preparing passengers for the upcoming landing. The crew carried out neither the before landing briefing, nor the APPROACH section of the checklist.

At 15:26:18 the Radar ATC officer instructed the crew to contact the Sheremetyevo Tower C1 sector ATC officer. The crew managed to establish the two-way contact with the Tower controller just in a more than a minute (see Section 1.18.25 of the Report for details).

At 15:26:30 the crew set the 7700 squawk code. The reasons for the setting were not relayed to the controller.

At 15:27:14 the target IAS was set to the value of 155 kt (287 km/h), which is consistent with the reference approach IAS for actual conditions.

At 15:27:20, from the distance of ~ 11.3 km off the RWY 24L entry threshold and the altitude of ~ 600 m QFE, the glideslope descent was initiated. Compliant to the approach pattern (Fig. 29), the FAF is located at the distance of 9.3 km, the altitude of the glideslope capture is at 500 m QFE. Upon the glideslope interception the altitude of go-around was not set by the flight crew, which does not meet the FCOM provisions (item 1.04.72, page 3).

The flight data at the glideslope descent are shown on Fig. 155, so is the descent profile on Fig. 156.

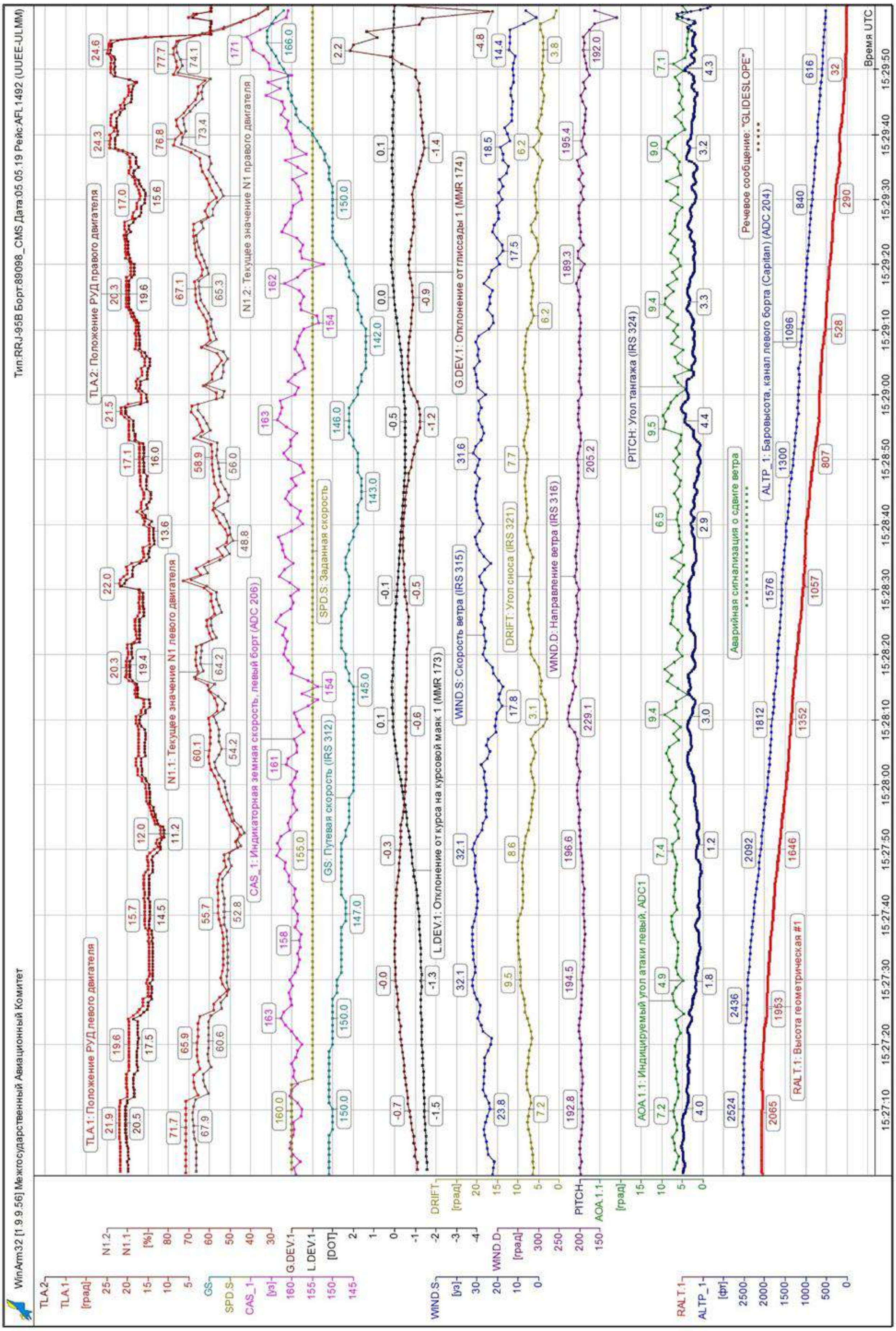


Fig. 155. The flight data at the glideslope descent

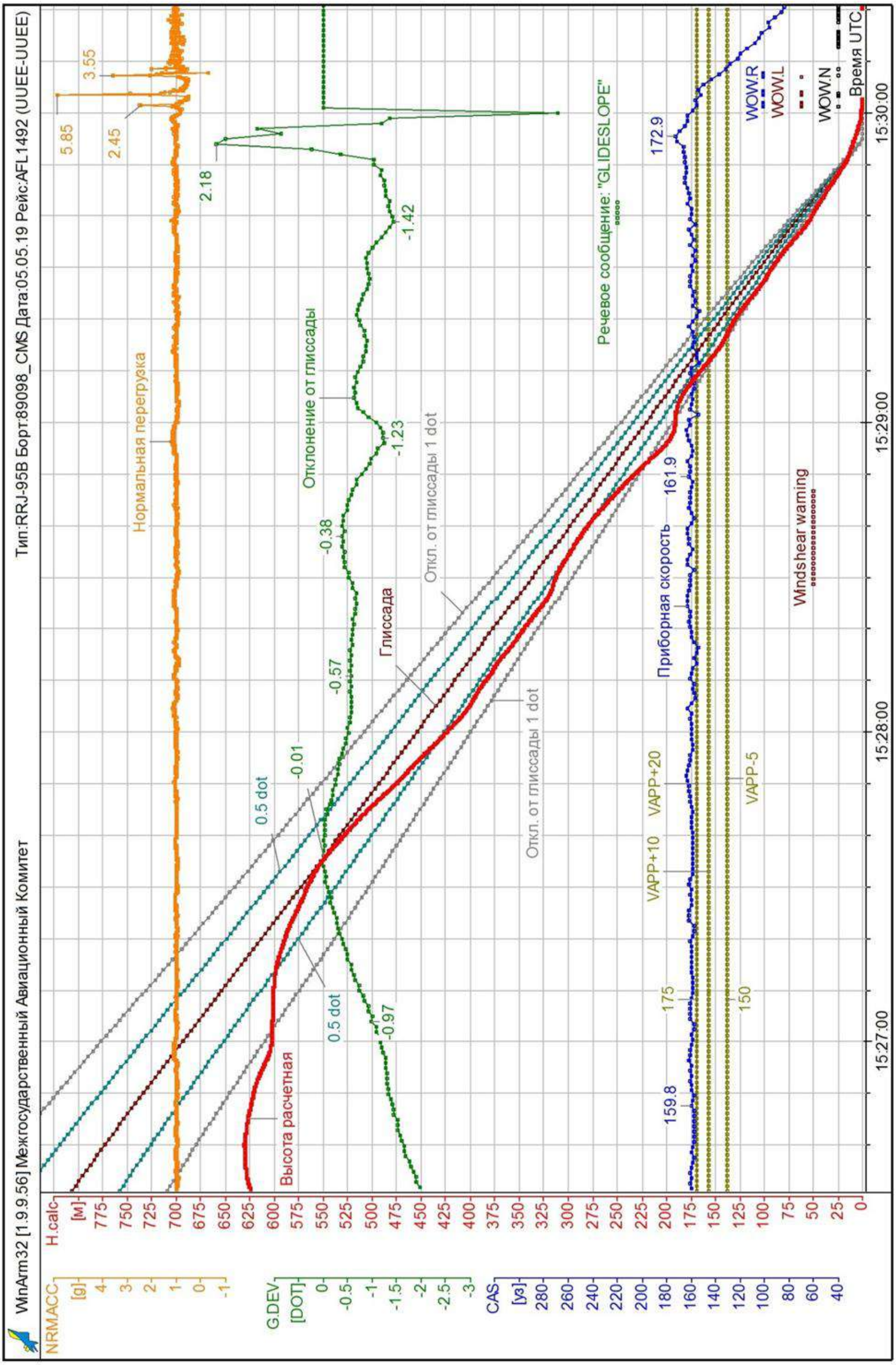


Fig. 156. The vertical profile of the glideslope descent

The glideslope descent was proceeded at the IAS of 155 – 160 kt (287 – 296 km/h) below (parallel to) the established glideslope track by about 0.5 – 0.6 dot, the deviation off the localizer equisignal zone did not exceed 0.5 dot.

The elevator tracked the pitch commands by the sidestick, which was periodically deflected by the pilot to nose-up by an average of 2°…3° (that is of 15 – 20 % of the travel). The sidestick pressure release in pitch by the pilot and its return to neutral resulted in the angular rate onset to the pitch decrease, that is the aircraft was balanced (trimmed) by the pilot with the residual back pressure. The TLA was changing between 11° and 20.5°, the N_1 was varying between 43 % and 69 %. The wind velocity at the glideslope was up to 30 kt (15 m/s) from the direction of 190°- 200°, the drift angle was equal to ≈ 8°.

At 15:27:51 the Tower controller relayed the weather information to the crew and cleared the landing: *«Aeroflot 14-92, surface wind 160 degrees 7, gusts 10 meters per second, runway 24 left, cleared to land».* The crew confirmed cleared to land.

At 15:28:26 at the passing of the QNH altitude of ~ 1600 ft. (490 m) (the radio altitude of 1100 ft. (335 m), the QFE altitude of ~ 1000 ft. (304 m)) the WINDSHEAR WARNING trigger is recorded (it is generated by the warning system to the crew based on the data of the predictive (forecast) windshear feature to the weather radar), accompanied by the *«GO-AROUND, WINDSHEAR AHEAD»* synthetic voice. This warning is to alert the crew on the potential presence of windshear ahead on the flight heading. The warning was kept triggered for 11 sec., within this time there were 2.5 warning cycles sounded (that is 5 synthetic voice messages, each cycle consists of 2 messages in a row with a 1 second interval between cycles). The flight crew did not discuss the activation of this warning.

At 15:28:38 the 1000 ft. (304 m) auto callout (the reaching of the true altitude value) was activated. The PIC made the decision to continue approach, which he called out to the F/O in an utterance: *«Continue»*, to which the F/O responded: *«Check»*.

At 15:29:21 after the 400 ft. (122 m) of true altitude auto callout activation the PIC called out that he had runway in sight and the approach might be continued.

At 15:29:22 the F/O warned of the approach to minimum. The PIC confirmed that the approach is to be continued. The F/O informed that the vertical speed at touchdown is to be not more than 360 FPM.

AT 15:29:31 at the QNH altitude of 870 ft. (265 m) (true altitude of 270 ft. (82 m), the QFE altitude of 250 ft. (76 m)) the synthetic voice was activated on the reaching of the minimum (the decision height) that was called out as well by the F/O. From this very point the rapid increase in the deviation (to 1.4 dot) below the glideslope equisignal zone is detected, which resulted in the activation of the «*GLIDESLOPE»* TAWS sound warning. The warning was kept triggered for 4 seconds. The PIC confirmed that he heard the warning by the utterance: *«Informative»*.

Starting from 15:29:44 the F/O constantly called out the current vertical speed to the PIC.

At the same time with the activation of the TAWS warning the PIC increased the engines power (the TL were reset to the 24°–23° position, which led to the N_1 increase up to 77–74 %). The engines increased power resulted in the increase of IAS: by the point of being flown over the RWY threshold at the altitude of 40 ft. (12 m) it increased up to 165 kt (306 km/h), by the altitude of 16 ft. (5 m) – up to 172.9 kt (320 km/h)[130] (the airline OM determines the margin of plus 20 kt as a stabilized approach criterion, see Section 1.18.7 of the Report).

At the point of being flown over the RWY threshold the true altitude was about 10 m, that is the aircraft was flown below the glideslope (when positioned «on the glideslope» RWY threshold shall be flown over the altitude of 15 m). After flown the RWY threshold there was a decrease of the sink rate. The flight data at the final stage of descent and at the landing are given on Fig. 157.

[130] The FDR records several values of the speed by different sources. Stated here is the maximum recorded value. The dispersion amounts to 2.6 kt.

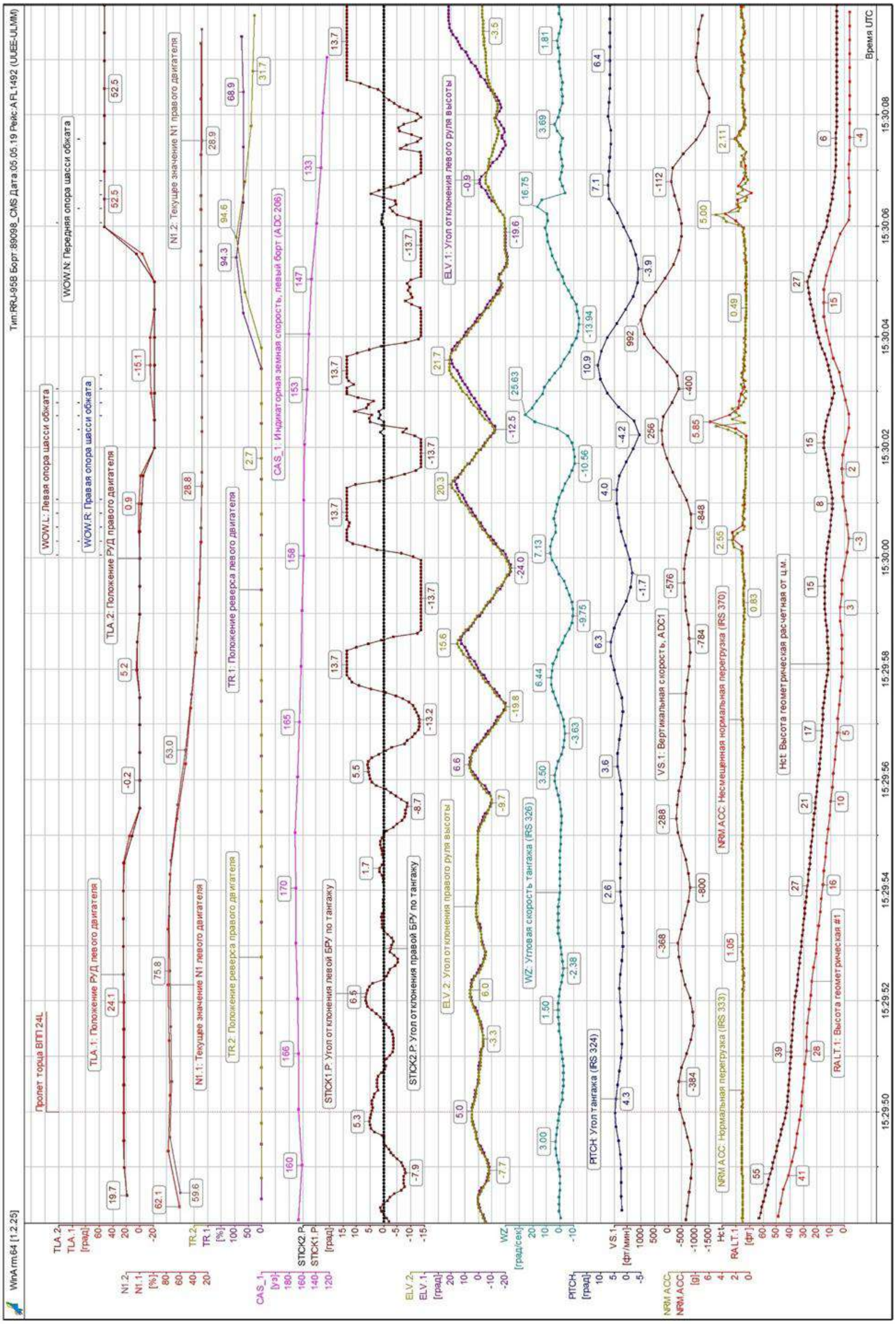


Fig. 157. The flight data through the final stage of descent and at the landing

At 15:29:54 at the true altitude[131] of 17 ft. (5.2 m) the RETARD. RETARD auto callout was activated, which indicates the reaching of the altitude to retard the TL to IDLE at flare. Concurrently with the callout activation the PIC initiated the retard of the TL.

Almost simultaneously with the TL retard to IDLE the PIC initiated the aircraft flare with the aft sidestick input by 8.8° (65 % of the travel). Further on the sidestick control inputs in pitch of the increased amplitude by the PIC are recorded up to the full travel, both the forward and the aft inputs with a relatively long keeping the sidestick retained against the stops. These control inputs resulted in the alternating changes of the pitch attitude (from 6º to nose up up to 2º to nose-down). At 15:30:00 at the distance of ≈ 900 m off the RWY threshold and the IAS of 158 kt (293 km/h) there occurred the first touchdown of the aircraft. The touchdown occurred with the pitch attitude, close to zero (at that the aircraft proceeded with the angular rate of 7 °/sec to nose-up), down on «three points» with the vertical acceleration of not less than 2.55G. Immediately prior to touchdown the sidestick was positioned against the aft stop, whereas in the progress of landing in 0.4 sec. (by the point of reaching maximum vertical acceleration) it had been a full forward sidestick control input with its subsequent keeping retained in this position for a second.

In DIRECT MODE the automatic deployment of the speedbrakes (spoilers) is disabled, the crew did not deploy them manually. After touchdown there occurred the separation off (the bounce) of the aircraft to the height of not more than ≈ 5 ft. (2 m).

Note: *1. According to information, submitted by the aircraft designer, the set of the functions of the alternate control modes for all aircraft, certified in compliance to AR-25 (CS-25, FAR-25), is determined by the fail-safety criteria, set out in the aviation regulations, uniform to all the aircraft types. In accordance with the fail-safety analysis that is based on the uniform criteria to all the aircraft types, the IN-FLIGHT INADVERTENT SPEEDBRAKES DEPLOYMENT event is evaluated as the HAZARDOUS or CATASTROPHIC FAILURE CONDITION subject to the flight stage.*

The FBWCS DIRECT MODE is essentially the simplest control mode, accomplished in the event of all the PFCUs failure, the absence of the signals by the interconnected systems or the data connections disruption between the FBWCS processors. The auto speedbrake deployment function implementation in DIRECT MODE requires redundant data by a number of systems (the radio altitude, the WOW to LG legs, etc.), which is not available as to this FBWCS mode.

[131] Hereinafter, unless otherwise stated, the true altitude values are given consistent with the radio altimeter indication, recorded by the FDR. See Section 1.18.28 of the Report for the features of the true altitude record.

2. Once after touchdown the speedbrakes are manually deployed in the FBWCS DIRECT MODE, then in case of go-around the speedbrakes are not automatically retracted, as in the FBWCS DIRECT MODE all the automatic modes are inoperative.

After the bounce for some time the sidestick was still kept retained in the full forward position, which resulted in the pitch angular rate increase up to 10.5 °/sec to nose-down, the rapid decrease of pitch attitude down to 4° to nose-down and another touchdown of the aircraft with the NLG coming first. Another touchdown occurred in 2.2 sec. after the first one at the IAS of 155 kt (287 km/h).

The NLG coming first at the significant vertical speed, as well as the full aft sidestick control input immediately before touchdown led to the onset of the aircraft intense rotation to nose-up. The recorded maximum pitch angular rate amounted to ≈ 25 °/s, and the vertical acceleration - to 5.85G at least. The result was the increase of the pitch and AOA, which, at the maintained significant IAS led to the other aircraft separation off the RWY to a great height (the porpoising phenomenon), despite the full forward sidestick input ahead of the aircraft bounce off the RWY.

Into the first touchdown, when the aircraft was airborne, the PIC set the TL to the MAX REV position, the TR doors had not been deployed, as there had been no WOW signals to the MLG legs. After the acquisition of the WOW signals of the left and right MLG legs the TR doors deployment was initiated and completed only after the second bounce of the aircraft off the RWY. There was no increase in the operating mode of the engines, since at that point there was no WOW signal again (see Section 2.3.4 of the Report).

The second bounce off the RWY occurred up to the height of ≈ 15 ft. (5 m). Shortly after another bounce the sidestick was deflected to the full aft position, and in ~ 2 sec the TL were set to the MAX position. These actions can be interpreted as the attempt to perform go-around, but as the TR had been actuated earlier (the doors were still in the opened position, although having started to stow), the engines thrust had not increased.

Note: *The FCOM, Section 1.03.15 PAGE 3*

The maximum engine power rating (MAX) corresponds to the maximum thrust… In the event of an emergency the pilot can get the MAX power rating manually by setting the TL on the MAX detent. The MAX power rating is certified and may be applied for not more than 5 minutes. The MAX power rating ensures the 10 % thrust increase against the TO/GA mode (the amount of thrust, consistent with the takeoff power in normal operation).

At 15:30:06 at the IAS of 140 kt (258 km/h) there occurred the third touchdown of the aircraft with the vertical acceleration of 5G at least. The nature of the traces on the RWY at the third touchdown is the evidence that the MLG legs by that point had been already partially destructed (the attachment A fuse pins sheared, see Sections 1.12 and 2.2.3 of the Report), the MLG legs had been broken under with the further destruction of the aircraft structure, fuel spillage and fire eruption.

The aircraft continued the movement on the RWY on the engine nacelles. As the MLG legs collapsed, their WOW signals had been lost and the flight phase (Fig. 44), detected by the FMS, had become consistent with phase 5 (takeoff/go-around). Due to the subject non-normal flight phase transition along with the mechanical damage and the fire effect, further on the FDR recorded the data on the non-normal operation of a number of the aircraft systems and the engines.

At 15:30:16 at the ground speed of 107 kt (198 km/h) the TR were again set to the MAX REV detent and remained in that position as far as the record stop. This input did not cause any change, the engines continued to run at IDLE, the TR doors were unlocked and could not be repositioned as the aircraft proceeded moving on the nacelles.

At 15:30:18 at the ground speed of ≈ 100 kt (185 km/h) the *Smoke and/or fire in the rear baggage/cargo compartment* discrete signal is recorded. Based on the results of the post-accident inspection the smoke and the increased temperature exposure to the baggage/cargo compartment ceiling panel is stated, for this reason it can be asserted that the warning system had functioned as assigned due to the onset of smoke and/or increase of temperature for more than 85ºC in the rear baggage/cargo compartment.

At 15:30:20 the F/O spoke out that the speedbrakes are not deployed and the TR does not function.

Up to the speed of 80 kt (148 km/h) the roll was proceeded largely along the RWY centerline at the fully pressed right pedal. Into the subsequent decrease of speed the heading began to gradually change to the left (into the wind). At 15:30:25 at the speed of 65 kt (135 km/h) within 4 sec. the pedals were repositioned (first the left pedal pressed to the full travel and then the right pedal pressed to the full travel again). This input resulted in the considerable increase of the rate of the turn to the left.

Note: ***As per the PIC's explanatory note:***

«Further on there had been a veering off from the runway and the counterclockwise turnaround. After we entered the turnaround I saw the smoke, the trail behind the aircraft. Smoke with fire. I realized the airplane is on fire».

At 15:30:41 the PIC called out: *«Emergency evacuation checklist»* (see Section 1.18.9 of the Report). The doing of the checklist section has not been recorded by CVR (see Section 2.2.6 of the Report for details).

At 15:30:53.3 the CVR stopped recording.

At 15:30:56 the passengers' evacuation was initiated through the right front passenger cabin door.

At 15:30:58 the APU FIRE BOTTLE EMPTY discrete signal is recorded, but there had been no discrete signal of the bottle discharge.

At 15:31:06-07 the FDR stopped recording. At the point of the record stop the engines continued to run.

At 15:31:10 the aircraft was completely powered off (determined by the switch off of the right landing light).

At about 15:31:34, as per the analysis of the video footage, available to the investigation team there had been the engines shutdown.

2.2. The analysis of the crew's condition and actions[132]

2.2.1. The analysis of the arrangement of the flight crewmembers' training and their authorization for air operations

Both flight crewmembers held valid pilot's licenses with the appropriate type ratings and were issued valid medical certificates. As per the submitted documents all the required recurrent drills and checks had been timely carried out. By contrast, the investigation team had identified a number of hazards, associated with the flight crewmembers' undergoing of the training programs and the arrangement of the air operations activities in the airline, which pose risks to the aviation safety and may have adversely affected the quality of the pilots training.

The investigation team points out that as for the airline, at the arrangement of the air operations activities in general and at the pilots' training in particular the approach had been largely applied implying the practical implementation of one or another aspect only in case it is explicitly provided for by the regulations or the other documents' requirements. The proactive and predictive approaches, the risk assessment methods and these aimed at identifying deficiencies in the pilots' training until they cause negative consequences had not been sufficiently applied.

Note: ***As, for instance, responded by the airline to the investigation team requests (see Section 1.5.1 of the Report for details):***

- no detailed description of each abnormal and emergency procedure drill scenario (including the F/CTL DIRECT MODE as well) into the RRJ-95B Aircraft Transition Training Program is due to no specific requirements of the FAR;

- there are no requirements to provide material (the supporting evidence) on the associated failures into the drill of the specific elements or procedures in the regulatory documents.

[132] It is only these crew's actions analyzed that apply to the circumstances of the air accident.

The flight crew training programs integrated a number of provisions, allowing for the ambiguous interpretation (see Section 1.5.1 of the Report for details). With that the flight and command personnel to the airline, who had been in charge of the pilots' recurrent/training, «had interpreted» all the ambiguities towards the reduction of the amount of training. Thus for instance the PIC's authorization for the commissioning on the completion of the recurrent training had been carried out without holding the aerodrome drill (or the ZFTT drill). The PIC had been authorized for commissioning without the examiner's conclusion (remark): *«May undergo the training to perform solo air operations».*

At that the PIC had undergone additional training under the number of programs and exercises that initially had not been a part of the established Variant of the training. Presumably, by the instructor personnel's opinion, the approved standard amount of training might have been insufficient to the PIC to acquire the necessary knowledge and skills. What is more, as for the training to perform flights as a PIC, its variant had been altered towards increasing the amount. The investigation team notes the «the closeness» of the instructor and flight and command personnel to the airline. The airline did not stated the specific reasons, on which the amount of training had been increased (the Variant had been subject to change).

Note: *By his previous experience the PIC had met the training Variant 1 requirements (the minimum amount). Originally (at the training as a F/O) the decision had been made on the increase of the training amount and Variant 2 had been chosen. In the Flight Experience Record there is no justification for this decision. In the course of the investigation the airline alleged as its reason «the inexperience of air operations aboard the aircraft with FBWCS». The training as a F/O had been entirely carried out under Variant 2. At the training as a PIC Variant 2 had been changed to Variant 5 halfway through the process, there is no justification for this decision in the Flight Experience record either. When reviewing the draft Final Report, again, the airline reasoned the Variant change by the «inexperience of the air operation aboard the aircraft with FBWCS», which sounds illogical as the PIC should have acquired the required skills of the FBWCS aircraft operation by successful completion of the F/O training program. At that the training as a PIC under Variant 5 had not been carried out in full (from the beginning).*

Into the progress of the investigation this policy had not been changed indeed. Neither of the instructors, who had conducted the recurrent simulator training or the drill to the flight crewmembers, had submitted no information on the procedure and actual amount of the conducted training, «having got rid of» with the formal replies. The mentioned facts, along with the absence of the detailed documenting[133] of the training process prevent the comprehensive assessment of the actual amount and the quality of the flight crewmembers training, including this to operate through different legs of the flight at the FBWCS in DIRECT MODE (see this Section here below as well)), as well as the determination of all the factors that had not allowed the airline to timely detect the existing deficiencies in the flight crewmembers' training and offer recommendations on the mitigation of the relevant risks.

The performed analysis of the transition training and commissioning programs undergoing by both the PIC and the F/O (although they had underwent training at different times) was the evidence that the airline failed to consistently comply to the requirements on the assignment of the flight instructors to the trainee pilots. Probably because of the haste[134] in the pilots training (the next stage of training had often been initiated before the issuance of the associated documents) and the involvement of the flight instructors in the performance of the airline flights, the available instructors had been invited «as a residual». Eventually the essence of the instructors' assignment institution had been lost - the assigned instructor is to continuously observe the trainee's progress, having the comprehensive knowledge on the trainee's proficiency and his/her weak spots that require the specific focus. With several instructors a specific one is not able to continuously observe the trainee's progress, which may adversely affect the acquisition of the knowledge and correct sustainable skills. This is especially true when the outcomes of the training programs undergoing are not thoroughly documented.

This conclusion is supported confirmed at the analysis of the PIC's piloting technique at flare and landing (see Section 1.16.19 of the Report). The available material is the evidence that into the entire RRJ-95 flying time the correct sustainable skill of performing flare, as recommended by the FCOM, was never developed at the PIC. This shortcoming, explicitly affecting the safety of landing, into the entire period of the PIC's employment in the airline had not been identified and rectified by the instructor personnel.

Note: *This is the absence of the **sustainable skill** of the flare and landing performance at the PIC that the investigation team concludes about over here. The analysis of 37 randomly selected flights was the evidence that through some of them the flare and landing had been performed with no comments. By contrast, various deviations (hazards) had been manifested in a number of the other flights, which*

[133] The detailed documenting of the various processes is one of the basic principles of the modern SMS design.
[134] The airline air operations safety work group Minutes of Meeting # 8 of September 8, 2015 over the year 2015 are available to the investigation team. The Minutes of Meeting inter alia noted the issue of the insufficient number of the flight crews against the actual RRJ-95 aircraft fleet or the low-quality planning to comply with the OM item 2.3.3 «The air operations safety ensurance».

themselves against the assigned conditions for landing and the operative safety margins (protections) may not lead to the major adverse effects.

Still at the in-flight emergencies, when the safety margins (protections) are degraded or inoperative, the mentioned hazards may set off the sequence of events, resulting in the air accident.

Through the investigation process the airline stand on this issue had been communicated to the investigation team, involving that «it is the uniform optimal flare profile ensurance that is crucially important, ***rather than what pilot's control inputs it is accomplished by****».*

The investigation team does not accept the second (highlighted) part of this statement. The lack of the correct sustainable skills of the flare performance dramatically increases the risk of non-establishment of «the uniform optimal flare profile», that is the process, leading to the aircraft landing within the established zone and at the recommended values of VS and IAS, as well as the pitch attitude. This is what is confirmed by the results of the analysis of the landings, having been performed by the PIC, in a number of which various deviations had been recorded.

The risks in question grow intolerable, when the pilots permit themselves (believe it possible) the control inputs, explicitly prohibited by FCOM – the forward sidestick input beyond neutral once the flare is initiated. This stand is shared by virtually all modern transport aircraft manufacturers[135]. It is the unacceptability (the catastrophic consequences) of subject risks that had manifested itself in the air accident under discussion.

Taking into account the FCS feature, implying the sidesticks are not linked, the instructor personnel is unable to directly monitor the PF sidestick position. It is only the flight path shift in pitch that the PNF is capable to monitor. That is to say until the piloting deficiencies, stated here above, do not result in the considerable deviations off the target flight path, they (the piloting deficiencies) may go unnoticed.

As explained by the airline representatives, the software in use for the board recorders data analysis prevented the automated identification of the PIC' piloting technique features and deficiencies, outlined in Section 1.16.19 of the Report.

Meanwhile, the above mentioned «constraints» for the identification of the piloting technique deficiencies (being the hazards by nature) are long known. The risks that they pose

[135] See for instance THE AIRBUS SAFETY MAGAZINE (Safety first – September 2020).

should have been evaluated by the airline as a part of SMS and the corrective actions should have been taken on their mitigation.

The obvious way of mitigation (monitoring) of this type of risks is the expertise of the board data recorders records. The investigation team points out that at least at the transition training and commissioning for the new aircraft type, when the piloting skills are developed (established), this kind of the «manual» (expert) monitoring insofar the automated methods «do not work» is the only way, allowing for the timely identification and addressing of the deficiencies.

When it comes to the PIC, such an expert evaluation would almost certainly make it imperative to arrange further in-depth analysis of his piloting technique, as, inter alia, he had the sustainable skill of the full forward sidestick input at the takeoff run and landing roll, which immediately catches the eye at the expert analysis of the records and is inconsistent with the RRJ- 95 aircraft FCOM provisions (see Section 1.18.31 of the Report as well).

Apparently, this expert evaluation of the PIC's piloting technique had not been undertaken by the airline. With that as of the date of the air accident the PIC had been undergoing the training to get the instructor's authorization. Against the indicated deficiencies in the PIC's piloting technique (manifested, inter alia, into the flights to get the instructor authorization) the airline decision on his commissioning as the instructor seems unreasonable.

At the airline the insufficient attention had been given to the aviation psychology issues. This way, the F/O had been authorized to the type transition training without undergoing the mandatory psychological testing that had been drawn up not until the actual completion of the training. The airline may have been «retroactively» certain in the «successful» passing of the testing (the psychological support had been ensured by the experts of the airline in-house medical center), otherwise it would not have spent resources on the transition training. This assumption is supported confirmed in the fact that the psychologist, having been employed as the airline health center psychologist from 2003 and as a MFEC psychologist from 2010, testified at the interview that into her entire working experience in the airline she had never faced «the failure to pass» the psychological selection. Generally the investigation team is not aware of any single occurrence of the airline pilots' failure to pass the psychological selection. In view of rather stringent requirements of the Manual on Psychological Selection in the Civil Aviation of the Russian Federation and the significant number of pilots of different ages, employed by the airline, this calls for reasonable doubts as far as the quality and «integrity» of the psychological selection conduct are concerned. It should be pointed out as well that at the apparent «peculiarities» of the PIC's psychological profile (see Section 1.16.21), including their («the peculiarities») manifest in the later variants of the testing the additional examinations had not been assigned and carried out.

Note: *Over a long period of time the documents to the PIC's psychological testing had not been submitted by the airline to the investigation team in a full package, they had been transferred not earlier than in late February 2020.*

The assessment of the sufficiency of the training amount to perform flights at the FBWCS DIRECT MODE

The approved RRJ-95 aircraft type transition training, under which the PIC and F/O had underwent transition training, provided for the training at the FBWCS operation in DIRECT MODE (see Section 1.5.1 of the Report for details). It provided for, inter alia, the simulator training at the different legs of the flight, including the approach and go-around. The flight crewmembers at the post-accident interviews had stated that the training in question had been arranged to them as a part of transition training. In contrast the transition training reporting documentation does not read the data on the specific flight modes and stages. Thus it has not been possible to reliably determine the actual amount of training to perform flights at the FBWCS in DIRECT MODE, acquired by the pilots into the type transition training.

The general requirements to the flight personnel recurrent training programs are determined by FAR-128. Item 5.84 stipulates: *«An operator shall prevent aircraft flight crewmembers from performing their duties unless they are trained under the training program, designed by the operator, that ensures the flight crewmembers are appropriately trained to perform their assigned duties»*. The sub-tem e) of the FAR-128 item in question specifies that the recurrent training program shall provide for, inter alia:

«the theoretical training at least once during 7 consecutive months to perform standard procedures to air operations and act in emergencies, including passing the exam, and the drill on a flight simulator, including the check;

at least once every 36 consecutive months the drill on the flight simulator to practice the failures to all the systems, not attributable to the emergency, including the check».

These are the requirements only that are determined by the indicated FAR-128 provisions, but not «the order» of practicing of each specific emergency. The operational documentation to the modern highly automated aircraft contain the significant number of the abnormal situations and emergencies. The RRJ-95 QRH list of these incorporates 450 items approximately[136]. Apparently there is no way to arrange «every single» practice of such a number of emergencies within a half-year (for the emergencies) and a three-year (for the remaining abnormal procedures) cycles. To practice all the stipulated events the operators have «to merge» them.

[136] As to the A320 family, roughly the same number of the abnormal and emergency procedures is stipulated, as for the Tu-154M airplane the number of these is about 40.

As per the RRJ-95 aircraft FCOM the F/CTL DIRECT MODE is «an abnormal situation»[137], i.e. this is not an emergency and shall be practiced with each pilot at least once in 36 months.

The airline programs of the pilots' recurrent training did not provide for the specific practice of the F/CTL DIRECT MODE abnormal situation. As evidenced by the airline command and flight personnel, the practice of the situation in question had been combined with the other emergencies, at the occurrence of which the FBWCS reverts to DIRECT MODE. This had been confirmed by the pilots as well at the post-accident interviews. At that for most cases the very fact of the F/CTL DIRECT MODE practice had not been even introduced in the drill assignment form. The investigation team points out that this kind of the «incidental» attitude to the F/CTL DIRECT MODE abnormal situation till the day of the air accident had been confirmed by the representatives of several other RRJ-95 operators at the technical conference, having been held at the aircraft designer facilities after the air accident.

Indeed at the practice of a number of abnormal events (the unreliable airspeed indications, for instance) the FBWCS will automatically revert to DIRECT MODE. By contrast, at the assessment of the further actions by the crew the instructors will focus attention most of all on the performance of the «basic» procedure, attributed as the emergency. At that the practice of the piloting in DIRECT MODE and the assessment of the pilot's capability to operate the aircraft in this mode are not a priority. Besides, depending on the «basic» exercise scenario, the piloting in DIRECT MODE may be performed a short while, not at all stages of the flight, which prevents the objective assessment of the respective skills.

As outlined in Section 2.2.5 of the Report, as far as the PIC's piloting technique into the flight that ended up with the accident is concerned, the typical errors, apart of the forward sidestick input beyond neutral at flare, had been as follows:

- the aircraft out-of-trim condition in pitch channel over different stages of the flight, including at the glideslope descent;
- the ducking under the glideslope at final descent;
- the dynamic sidestick inputs at the consecutive bounces of the aircraft off the RWY;
- the failure to deploy speedbrakes manually after touchdown.

At that, the similar deficiencies had manifested to some extent at the previous events of the landings in DIRECT MODE, having been performed by the other airline pilots (see Section 1.16.19 of the Report). The investigation team notes that, taking into account the difficulties at the flight performance in DIRECT MODE that had been observed at the different flight crews to the

[137] This assignment is assessed by the investigation team in Section 2.2.5 of the Report.

airline at least from 2015, Aeroflot, PJSC had grounds to introduce the F/CTL DIRECT MODE abnormal situation in the list of occurrences, being subject to the «specific» practice and better monitoring.

Note: *The air operations safety work group Minutes of Meeting # 8 of September 8, 2015 over the year 2015 had been submitted to the investigation team by the airline.*

As per the document in question, at the meeting «three occurrences[138] *of the aircraft reversion to DIRECT MODE had been reported». The flight personnel had been briefed on this, the associated safety recommendations and actions had been developed. As from September 9, 2015 the air division management made the decision that the simulator training program should be supplemented with the piloting aspects and the arrangement of the activities at the aircraft reversion to DIRECT MODE.*

However the Minutes of Meeting do not indicate the specific technical aspects the flight personnel had been briefed on. With that, as outlined in Section 1.16.19 of the Report, two out of three events in question had not been formally investigated at all, and the investigation into the third occurrence had not revealed any deficiencies in the flight crew actions. Likewise the Minutes of Meeting do not specify the additional actions as referred to the simulator training. In the course of the investigation the airline had been unable to specify the subject aspects.

Based on the review of the previous occurrences the aircraft designer may have come up with the initiative that the respective amount of training should be increased to this aircraft type, despite the FBWCS reversion to DIRECT MODE is not an emergency. The investigation team is of the opinion that the list of abnormal situations, being subject to the «specific» practice, should be continuously updated for every aircraft type. The selection of the events of the kind should be based on the risk assessment and the synthesis of the operational experience of the specific type, as well as on the results of the air accidents investigation. The aircraft designers should be as well involved in this kind of activities.

2.2.2. The analysis of the crew's actions prior to the initiation of takeoff

According to the OM Part B «The preparation for flight» item 2.2.2 «Weather Briefing» prior to the flight the crew, inter alia, shall check the presence of the significant weather and the

[138] The note by the investigation team: these are the first three events out of the Table in Section 1.16.19 of the Report.

sequence of its avoidance, whereas at the thunderstorm environment, adjacent to the aerodrome to evaluate the safe departure en route. The FCOM (Section 1.04.15 «The preparation for flight») reads the similar provisions. Likewise the OM (Part A, Chapter 8 «The operating procedures», Section 8.3.9 «The flights in different weather conditions», subsection 8.3.9.2 «The flights in the area of thunderstorm activity and strong shower rains») stipulates: *«At the presence of the cumulus congestus and cumulonimbus cloud at the area of the aerodrome the crew shall inspect the takeoff and departure out of the aerodrome zone area with the use of the aircraft radar, evaluate the feasibility of takeoff and determine the sequence of the avoidance of the cumulus congestus and cumulonimbus clouds and the zones of strong shower rains».*

Note: ***As by the PIC's explanatory note***

Together[139] we reviewed the flight documents … weather (actual and forecast)...

At the takeoff briefing at 14:20 the PIC pointed out: *«… no significant weather…»*. By contrast according to the weather data that the PIC had obtained as a part of the preflight preparation the thunderstorm had been forecast and observed at the aerodrome area (see Section 1.7 of the Report).

Note: *According to the ATIS information, at the time period under discussion there had been no in situ thunderstorm observed at the aerodrome[140].*

At the preflight check of the weather radar the crew had not stated any comments on its function. In the progress of the investigation the investigation team had not identified any signs of the non-normal weather radar operation. As evidenced by the PIC the weather radar had functioned in the automatic mode, its image had been displayed at the ND.

The analysis of the crew communication allows concluding that prior to takeoff the crew at least twice had talked about «the clutters». At that for the second time, having been already lined up, was observing them at the weather radar screen, including these in the direction of the target SID.

At lineup the PIC had changed the ND scale six times over the range of 5 nm (9.3 km) - 20 nm (37 km). At the point of the PIC utterance *«The clutter, can you see (en rou…)? »* –, the scale of his ND had amounted to 20 nm (37 km). At that, according to the data by the Vnukovo TDWR the zone of the thunderstorm activity had been allocated at the distance of 33-35 km off Sheremetyevo aerodrome. In view of the altitude, at which the aircraft had encountered the lightning and the performance of the weather radar the crew may have been able to observe

[139] With the F/O.

[140] According to the METAR, SPECI, TAF codes Guidance materials the data on the cumulonimbus cloud and thunderstorm falls into the aerodrome and its vicinity. At that the vicinity refers to the aerodrome adjacent area, which distance is from 8 to 16 km off the ARP.

«clutters». Equally the PIC, while talking with the F/O, had expressed hope that the SID would be changed.

At the post-accident interview the PIC had stated that at lineup he had checked the takeoff area with the use of the weather radar, there had been nothing to impede the takeoff.

Note: ***As by the materials of the PIC's interview:***
«The weather environment was simple at lineup. I inspected the takeoff area, the weather formations of the green color[141] *were noted out of the SID. Accordingly, the avoidance was not anticipated».*

The investigation team points out that this evidence is inconsistent with the Vnukovo TDWR data and the CVR record (the PIC, taking into account his extensive flying experience, would hardly repeatedly focus on the «clutters» of green color that did not imply avoidance and even express hope for the SID change).

The comparison of the indication by the Vnukovo TDWR and the weather radar, installed at the RRJ-95 aircraft type is the evidence that the aircraft weather radar is more conservative (Section 1.16.11 of the Report). As at the location of the actual aircraft exposure to the static electricity according to the data by the Vnukovo TDWR «the clutters» of the red color had been observed, then at the serviceable condition of the aircraft weather radar the crew should have observed «the clutters» of the red color as well, that is to say the PIC's words on the observation of the «green» clutters only, most probably, are inconsistent with the reality.

Note: *According to the FCTM Section 04.60 «Use of Radar», one of the main functions of the weather radar is to identify hazardous weather phenomena and display the color-coded areas of different precipitation intensity and turbulence to the pilot. It is important to understand that the function of the weather radar in determining areas with hazardous weather phenomena is based on the evaluation of the signals reflectivity from water drops. The intensity of the reflected signal depends on the size of the droplets, their composition and quantity. The wet hail is of the highest reflectivity, whereas the dry snow is of the lowest.*
The display of the weather radar image on the ND screen is enabled with the color coding. At that the light rain areas are coded with green color, medium rain areas with the yellow one, the heavy rain areas are red-coded. The areas of turbulence are colored magenta.

[141] The provisions of the OM Part B item 3.13 do not contain requirements to avoid green areas, indicated by the RDR-4000 aircraft weather radar, at the detection of the weather formations on altitudes of not more than 28000 ft (8534 m).

Thus, as there had been no discussions on the sequence of avoidance of «the clutters» and the safe ways to enter the route had been recorded by the CVR, the investigation team believes that the above mentioned OM and FCOM provisions had not been carried out by the crew prior to takeoff. The failure of the crew to carry out these provisions had contributed to the aircraft entrance in the thunderstorm activity zone and its encounter the atmospheric electricity.

2.2.3. The analysis of the crew's actions up to the point of exposure to lightning

The takeoff and initial climb had been generally proceeded uneventful.

However it is worth noting that at the post-accident interview the PIC stated that at the takeoff run and into initial climb the scale of his ND had amounted to 2.5 nm and that he always used this scale. The analysis of the data recorders content had been the evidence that into the preflight checks up to the point of the aircraft exposure to the atmospheric electricity the PIC's ND scale had never been less than 5 nm.

Into the takeoff run the PIC and F/O's ND scales, having displayed the weather radar indications, amounted to 5 nm (9.25 km) and 10 nm (18.5 km) respectively, that is to say at this stage of flight none of the crewmembers had been able to observe the thunderstorm activity zone. Later on the PIC's ND scale had been increased up to 10 nm (18.5 km) and this to the F/O – up to 20 nm (37 km). With these settings the PIC had been still unable to observe the thunderstorm activity zone. The F/O could have been observed the subject zone, still no report on this issue by him to the PIC had been recorded by the CVR. This aspect had been degrading the PIC's situational awareness. It is guaranteed that the PIC had been able to observe the significant weather zone at his ND starting from 15:06:10 approximately, that is 2 minutes prior to the aircraft actual exposure to the atmospheric electricity. This is again confirmed with the repeated changing of the display scale starting from the indicated point of time.

Note: *The aircraft designer documentation and the airline OM do not explicitly specify the ND scales setting over the flight stages at the display of the weather radar data on it. However, as to the subject flight stage the FCTM suggests that all the yellow, red and magenta zones should be avoided at a minimum distance of 20 nm (37 km), which implies the display scale setting of 40 nm (74 km) at least. The weather radar Pilot's Guide suggests that at takeoff the PF should set the scale between 10 and 40 nm, and as for the PNF – one range higher.*

Up to the time of 15:07:10 the aircraft had been flown in the automatic mode strictly by the KN 24E SID, at that the AP functioned in the lateral channel LATERAL NAVIGATION/LNAV mode. Still at the point of time in question the AP operational mode in lateral channel had been changed to HEADING/HDG, which resulted in the earlier initiation of the right turn (Fig. 145) that is provided for by the SID. Along with this the AP operational mode had been changed by one of the crewmembers (most probably, by the PIC) without calling it out to the other crewmember. Until then the respective mode changes had been called out by the PIC and acknowledged by the F/O.

At the interview the PIC stated that into the avoidance it had been the weather formations of the green color only, which he tried to avoid within the route *«for a more comfortable proceeding of the flight»*, without requesting the ATC clearance for avoidance.

The aircraft, having departed right before and after of the RA-89098 and flown by the same route within the time interval in question (the AFL274 and AFL1426 flights), had both requested[142] the right turn to avoid the thunderstorm activity at the ATC (see Section 1.18.1 of the Report as well). Fig. 158 - Fig. 163 present the frames from the ATC radar with overlapping of the Vnukovo TDWR data, showing the relative positions of the aircraft at the specific points of time. The analysis of the images in question is the evidence that the other flight crews had requested the avoidance and entered the turns earlier. At that the AFL1426 flight had been performed aboard the sister airplane at the interval of a minute approximately, that is to say the weather data images should have been roughly the same to both aircraft.

Note: *At the analysis of the images data it should be taken into account that the TDWR data are updated once every 10 minutes on the display. The thunderstorm cloud had been shifted to north-east with the velocity of 15 m/s, in other words within the time interval between the closest approach to the clutters by the AFL274 and AFL1426 flights the shift had amounted to about 2.2 km.*

[142] The requests of avoidance by these aircraft are not recorded by the CVR, as at the point of these requests the RA-89098 crew communicated on other frequencies.

Fig. 158. The AFL274 flight (highlighted with red color), the point of request of the 300° heading for avoidance

Fig. 159. The AFL274 flight (highlighted with red color), the point of the closest approach to the thunderstorm front

Fig. 160. The AFL1492 flight (highlighted with red color), the onset of the deviation off the KN 24E SID

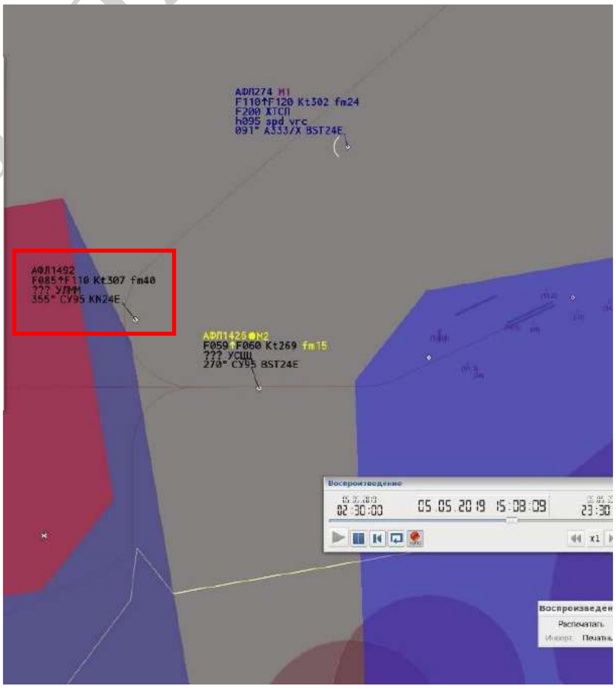


Fig. 161. The AFL1492 flight (highlighted with red color), the point of the atmospheric electricity strike against the aircraft

Fig. 162. The AFL1426 flight (highlighted with red color), the point of the request of heading to the right to BST24E

Fig. 163. The AFL1426 flight (highlighted with red color), the point of the closest aircraft approach to the thunderstorm front

The analysis of the crew communication (the PIC: *«It is going to bump now»*) and actions (the activation of the continuous ignition mode to both engines) at this leg of flight indicates that the crew had been aware that the airplane entered the cloud with heavy precipitation and thunderstorm activity.

Note: ***FCOM, Section 1.04.60 «AFTER TAKEOFF»:***

«…

Set ENG START to IGN/ON position, if severe turbulence or heavy rain is encountered».

The aircraft had been struck by the lightning at 15:08:09.7 at the altitude of 8685 ft. (2647 m) QNE. As per the data of the atmosphere radiosonde observation over the time interval under discussion, at the altitude of 2000 m the air temperature amounted to 2.4°C and at the altitude of 4000 m it was M9.9°C. It is known that the highest recurrence and the intensity of lightning are observed within the zero isotherm zone[143], which aligns well with the stated actual data.

Thus the investigation team makes general conclusion that the crew had not followed the provisions of the FAR-136 Section XXXII «The flight in thunderstorm activity and heavy precipitation» items 162, 163, as well as the airline OM, stated in the Note here below. Indeed the

[143] See for instance page 100 in A.I. Yermakova «The peculiarities of the analysis and the weather environment evaluation to ensure the air operations safety on international airlines», Leningrad, Hydrometeorology Publishing House, 1987.

PIC had been late to initiate the avoidance of the zone of significant weather, which predetermined the aircraft exposure to atmospheric electricity.

Note: ***1. The Aeroflot, PJSC OM Part A Chapter 8 «Normal procedures», Section 8.3.9 «The flight in different weather conditions», subsection 8.3.9.2 «The flights in the thunderstorm activity and heavy precipitation zone»:***

«…

(3) At the approach of the aircraft to the thunderstorm activity and heavy precipitation zone the aircraft PIC shall evaluate the feasibility to proceed the flight and make the decision on the avoidance of the thunderstorm activity and precipitation zone with the coordination of these actions with the ATC (ATM) authority. When required request the vectoring at the ATC authority to avoid the thunderstorm activity zone.

The aircraft are prohibited to deliberately enter the cumulonimbus (thunderstorm), cumulus congestus cloud and heavy rainfall.

(4) The IFR flights into the thunderstorm activity and heavy rainfall zone without the installed onboard weather radar or at no ground radar control are prohibited.

At the in-flight detection of the cumulonimbus (thunderstorm) and cumulus congestus cloud by the aircraft weather radars the avoidance of these clouds is permitted at the distance of 15 km at least off the near boundary of the cloud blip at the radar display».

2. The Aeroflot, PJSC OM Part B Chapter 3 Supplementary Procedures Section 3.13 Aircraft weather radar:

«The fundamentals of air operations in the thunderstorm activity and heavy rainfall environment are stated in the OM Part A 8.3.9.2.

The RRJ-95 airplane is equipped with the RDR-4000 weather radar, the radar manufacturer suggests that at the detection of the thunderstorm cell the recommendations as follows should be followed:

- *arrange the avoidance at least 40 nm off the thunderstorm cell to timely coordinate the avoidance with the ATC;*
- *the avoidance is to be proceeded to windward, rather than downwind (it is less likely to encounter the turbulent downdraft or hail);*

- *at the arrangement of the thunderstorm cell the crew shall take into account the height of the thunderstorm cell and apply the procedures as follows:*
    - *to avoid amber, red and magenta zones within at least 20 nm ...».*

3. FAR-136:

«162. At the aircraft approach to the thunderstorm activity and heavy rainfall zone the aircraft PIC shall evaluate the feasibility of proceeding the flight and make the decision to avoid the zone of thunderstorm activity and rainfall with the coordination of these actions with the ATC/ATS authority.

The aircraft are prohibited to deliberately enter the cumulonimbus (thunderstorm), cumulus congestus cloud and heavy rainfall, except for the special flight missions.

163. ...At the in-flight detection of the cumulonimbus (thunderstorm) and cumulus congestus cloud by the aircraft weather radars the avoidance of these clouds is permitted at the distance of 15 km at least off the near boundary of the cloud blip at the radar display».

At the post-accident interviews the flight crewmembers stated that prior to takeoff and further into the flight before the airplane encountered atmospheric electricity only the «green» clutters had been displayed at the weather radar, those should not have been avoided.

The investigation team assumes that this statement by the crew is not the case. This finding is supported by the facts as follows:

– there are no data on the weather radar failures either into the flight that ended up with the accident, or into the previous flights;

– prior to takeoff the crew had been observing «clutters», which had been of concern to the crew (apparently not of the green color), right up to expressing wishes on the SID change;

– the crews to the other RRJ-95B type aircraft (with the same weather radar model installed) in the meantime had requested clearance and performed avoidance of the thunderstorm activity zones;

– the PIC manipulated the ND scale, which the weather radar data are displayed on, within the time, preceding the aircraft exposure to the atmospheric electricity. The set scales enabled the observation of the heavy rainfall zone;

– at the last moment the crew actually attempted to avoid the zone of the significant weather.

2.2.4. The analysis of the crew's condition and actions after the exposure to the atmospheric electricity and till the initiation of the final approach

Initially after the aircraft had encountered atmospheric electricity the PIC replied negative to the question by the F/O *«Shall we request a return?»*. Still in a second the PIC uttered: *«Yes, we will return»*. The experiment had been the evidence (see Section 1.16.3 of the Report) that at that time the multiple failure messages[144] should have been displayed at the EWD. The investigation team is of the opinion that into that environment the decision to return with the declaration of the PAN–PAN urgency signal had been taken appropriately.

Note: *As to the modern highly automated airplanes there are occurrences of the failure messages display to the crew in such a quantity that it is physically unable to handle within a reasonable time at the performance of the procedures, provided for by the operational documentation as for each failure. At that often there is one «original» failure (in the case under discussion it is the EIUs reboot), and the rest of «the failures» (CAS-messages) are the consequence of the original one. In this environment the crew is to experience substantial difficulties with the attribution of the «original» failure and its required actions (particularly – as in the case in hand - if the failure itself is not displayed to the crew). The results of the investigation of the other air accidents (for instance, the fatal occurrences to the A330 aircraft on June 1, 2009 over the Atlantic ocean and to B737 MAX on October 29, 2018 in Indonesia, as well as the serious incident to the Airbus A380-842 VH-OQA aircraft on November 4, 2010 in Indonesia) are the evidence that the identification of the «original» failure may be extremely difficult and time-consuming or even not feasible to the crew. At that, anyway, «the string lights» of failures lead to the substantial crew «overload» and the increase of the psychoemotional tension even up to the psychological incapacitation*[145].

This is how the flight crewmembers at the interview described their impressions into the flight that ended up with the accident after the aircraft encountered atmospheric electricity. The PIC: *«… Then it was a bang and the bright flash. The entire EICAS display was filled with the orange messages, the failure ones and the DIRECT MODE synthetic voice sounded»*. F/O: *«It was as the downpour maybe that's it. We are entering inside and suddenly at it happens the bright flash, the so mighty bang and it was felt that the airplane hull was exposed to something. As when the electrical «shorty» occurs if one sticks the fork in the socket. Something of the kind went*

[144] At the post-accident interview the crewmembers confirmed the display of multiple failure messages, which «*over time had been no longer displayed*».
[145] The loss of efficiency and purposefulness of mental activity. In this condition, the pilot physically enables control, replies in the words, but his actions are clearly inconsistent with the current environment.

throughout the hull. And that's all. At once the Flight Director, the autopilot are out … and right away the DIRECT MODE synthetic voice [triggered] twice and DIRECT MODE was displayed on the screen.

In the light of the above, the aircraft exposure to the atmospheric electricity may have had the effect of «surprise» on the crew, which is supported by the emotional exclamation by one of the crewmembers: *«Gosh»*. In addition the «surprise» may have been intensified by the appearance of the substantial number of failures on the EWD that had been mentioned here above. This effect, most probably, induced the explosive increase of the psychoemotional tension at the flight crewmembers and affected the further succession of events.

Note: *1. The FAA AC120-111 advisory circular revision 1 reads the following definition of the «surprise» – an unexpected event that violates a pilot's expectations and can affect the mental processes used to respond to the event.*

2. After the aircraft encountered the atmospheric electricity the crew's operational quality as far as the SOP are concerned had been substantially degraded, including identified numerous instances of the modes change and the setting of the target flight parameters without the associated callouts (reporting) and the acknowledgement (check), the failure to carry out the checklist sections, to relay mandatory reports to ATC and the performance of maneuvers without the ATC clearance, etc.

Compliant to the Aeroflot, PJSC OM item 8.4.1.2 the PIC (the crew) shall promptly report the onset of the in-flight emergencies to the ATC. If the radio communication via the main channel is complicated then it is required to transition to the emergency frequency of 121.5 MHz

The subject OM item determines the list of the *«emergencies»* and *«abnormal»* situations, which should be reported to the ATC. The radio loss in the controlled airspace is attributed as the *«complex»* situation by the OM. In the case under consideration the crew had set the 7600 squawk code, which is stipulated by the OM Part A item 12.4.11. Into the further flight when the radio contact had been resumed, the crew had not removed this squawk code. At that the investigation team points out that neither the air legislation, nor the OM integrated the respective procedures.

Likewise the OM stipulates that the entrance to the significant weather zone should be relayed to ATC. The crew had reported the entrance to the significant weather zone and the aircraft exposure to the atmospheric electricity neither at this stage of flight nor later (while reporting the nature of failures aboard the aircraft). According to the CVR record the crew had not discussed that the aircraft encounter the atmospheric electricity should have been relayed to the ATC unit.

After the radio contact was resumed against the respective request by the ATC (at 15:10:36 *««Aeroflot 14-92, is it possible to contact on the general communication channel? »)*, the crew had been unable to ensure the radio communication at the main channels (on the main frequencies)[146]. At that the crew had never attempted to operate the serviceable VDR 3. Presumably this fact is indicative of the non-optimal psychoemotional condition of the crewmembers, under which there had been no respective reserves (the time and the psychological ones) to resume the radio communication on the operating frequencies with the use of the serviceable equipment. The crew had never been able to go beyond «the pattern» application of radio stations, described in the OM.

Note: ***1. The OM Part B page 2.1.2***

VHF1 is generally used to conduct radio communication with the ATM units; VHF2 is to get the ATIS data, the commercially relevant information and to monitor the emergency frequency;

VHF3 is used for the communication at the ACARS channels.

2. At the post-accident interviews both flight crewmembers stated that previously they had never run into either the in-flight FBWCS reversion to DIRECT MODE or the aircraft exposure to the atmospheric electricity. Altogether, neither of the flight crewmembers had ever got into the abnormal environment or emergencies into the line flights.

The increased psychoemotional tension of the crewmembers after the aircraft encountered atmospheric electricity is demonstrated as well by the transition to the Russian language at the external radio contact (earlier into the flight the radio communication had been proceeded in the English language).

After the aircraft encountered atmospheric electricity the FBWCS reverted to DIRECT MODE. To understand the further actions by the crew one should be aware of the «philosophy» (the principles of operation) of the FCS in NORMAL MODE and DIRECT MODE, including the differences in the modes in question.

Based on the information, given in Sections 1.18.14 and 1.18.15 of the Report, the following basic issues may be highlighted that should be taken into account by the RRJ-95 pilots at the operation in DIRECT MODE at the true altitudes of flight above 50 ft. by the radio altimeter[147]. As for the pitch channel this is the inoperability of the auto trim (balance) and automatic pitch attitude hold in response to the sidestick pressure release, no altitude hold in turn, as well as no compensation of the gearing (Cgear) out of the sidestick deflection against the airspeed at the unchanged flaps position. In the lateral channel there is no roll stabilization in response to the sidestick release and no turn coordination (the elimination of the sideslip).

[146] See Section 1.18.25 of the Report as well.

[147] The features of the operation in DIRECT MODE to be taken into account at the altitudes below 50 ft are set out in Section 2.2.5 of the Report.

These peculiarities should be explained to the pilots into the transition training and the recurrent checks, including the simulator ones. Understanding stated differences and the ability to handle them appropriately (with the use of all the available design features of the airplane) is just one of the goals of the professional transition training to the specific aircraft type.

The analysis of the performance evaluation by the test pilots (including the EASA ones), carried out as the outcome of the test flights both before and after the air accident, is the evidence that from the point of view of the pilot there are no crucial differences in the airplane performance in NORMAL MODE and DIRECT MODE. In summary of the evaluation in question the following is to be noted. In DIRECT MODE the satisfactory stability and controllability properties are ensured, as well as the control consistency between pitch, lateral and yaw channels that enable the flight to be completed safely. Against the NORMAL MODE, the significant increase of the PF's workload is observed at the stages of the substantial retrim of the airplane (the extension/retraction of the wing high-lift devices, the deployment-retraction of spoilers in the FLAPS 0 configuration) as the auto trim (balance) is inoperative and it is necessary to trim the airplane manually. It is with these trim peculiarities the FCOM reads the guidance on the in-flight spoilers deployment of half travel at most in the FLAPS 3 landing configuration (to prevent substantial retrim at go-around), whereas the situation itself of the reversion to DIRECT MODE had been attributed as *«the major failure condition»* one (see Section 1.18.12 of the Report).

Apart the findings on the results of the special activities, held after the air accident by the aircraft designer in association with EASA (on request of the latter), that is to say when the results of the preliminary investigation had been available, should be focused on. The activities had been proceeded on the simulator in Venice (Italy)[148] and aboard the real airplane. In the findings on the activities it is observed that the airplane performance in pitch channel in DIRECT MODE is acceptable. The flight aboard the appropriately trimmed (balanced) airplane does not induce the pilot's significant workload in maintaining IAS within the range of ± 5 kt and the altitude of ± 100 ft. The pitch controllability is acceptable into all the configurations, the airplane does not tend to oscillate (there is no tendency to APC, PIO). At the glideslope flight and landing, on condition the airplane is appropriately trimmed, there are no noticeable differences as far as the operation in NORMAL MODE and DIRECT MODE is concerned. At that in terms of the pilot's workload the stage of go-around is the most crucial as the substantial manual retrim is required. The consistency of the airplane and simulator behavior in DIRECT MODE has been stated apart.

[148] As per the information, provided by the aircraft designer, the engineering models, accomplished at the Aeroflot, PJSC simulator and at the simulator in Venice do not substantially differ, as far as the properties under discussion are concerned.

In view of the above we will look at the potential causes of the apparent difficulties, which the PIC had experienced at the manual operation of the airplane.

The analysis of the quality of the aircraft manual trim (balance) in pitch channel

As mentioned here above, one of the crucial differences as far as the operation in DIRECT MODE is concerned is that the aircraft should be trimmed manually in the pitch channel. As evaluated by the test pilots it is this aspect that causes the greatest difficulties, which the pilot experiences at the FBWCS reversion to DIRECT MODE.

It is common knowledge that the necessity of the significant retrim of any aircraft in pitch channel arises in three key cases[149]:

- the significant airspeed alteration;
- the substantial alteration of the engines power rating;
- the change of the airplane configuration (the extension/retraction of the wing high- lift devices and landing gear).

At the point of the FBWCS reversion to DIRECT MODE the airplane had been flown in the cruise configuration. The flight had been proceeded at the airspeed of ≈ 250 kt at the engines power rating of 86 - 87 % N_1. The stabilizer trim position had been 1.8° to nose-up.

At the FBWCS reversion to DIRECT MODE the AP had been disconnected as assigned. The flaps - as per the design integrated logic – had been automatically extended to 1° (the FLAPS ICE configuration), at that the crew had called out this issue. It is unclear whether the crew had even paid any attention to this change of configuration.

The flight in this configuration till the initiation of the wing high-lift devices extension at the preparation for landing lasted for 13 min. 30 sec. approximately. Into this stage the IAS of the aircraft was altered between 225 and 280 kt, the engines power rating was changing between 31 and 92 % N_1.

Hence it had been the occurrence of all the three conditions that require the airplane retrim in pitch channel. Still the PIC at that stage had never engaged the manual trim (the stabilizer setting) function, that is to say it is the sidestick input only, with which both the aircraft trim in pitch channel and its control had been enabled. As stated in Section 1.16.19, «the average out-of-trim» of the airplane in pitch channel into this stage had been consistent with the sidestick nose-up input to the amount of about 7 % of the available travel. This matter had not induced «the lack» of the pitch control, indeed had significantly increased the PIC’s workload and adversely affected the piloting quality (see that further below). Every time the sidestick was returned to neutral the

[149] The event of the significant one-time CG alteration is not covered over here.

pitch attitude started to decrease, in other words the airplane «nid-nodded», having been out-of-trim.

All in all, at the flight that ended up with the accident the PIC manually reset (trimmed) the stabilizer just four times within the time of 15:22:20 – 15:24:00 at the extension of the wing high-lift devices and landing gear. One more short press that had not resulted in the important stabilizer resetting, had been recorded on the glideslope. At that, as indicated in Section 1.16.19, in nearly all configurations the actual stabilizer deflection angle had been insufficient for the «normal» airplane trim. The lack of trim in the FLAPS 1/LG UP and FLAPS 3/LG DOWN configurations, denominated in the equivalent required sidestick deflection to nose-up amounted to about 15 % of the available travel. The airplane had been satisfactorily trimmed in the only FLAPS 2/LG DOWN intermediate configuration that had been established within a short interval of time.

With that into the flight in DIRECT MODE the PIC repeatedly pressed the sidestick PRIORITY / AP OFF pushbutton without any need as no F/O's interference in the aircraft control had been recorded throughout the flight. Each press had been a short-term one (one record sample at most) and had been accompanied with the trigger of the associated sound alert. The poll of test pilots and flight instructors with the experience of air operations and flight training (transition training) to both airplanes with the control wheel and the RRJ-95 showed that the PIC may have experienced the instinctive discomfort as the continued deflection of the sidestick in pitch had been required and these presses might have been the unconscious (reflex) skills transfer from the previously operated aircraft types (IL-76, Boeing 737) in an attempt to reset the stabilizer and trim the aircraft (release the sidestick pressure).

As far as the mentioned types are concerned the aircraft control in pitch and roll is enabled with the control wheel. The stabilizer manual control is done with the use of two stab trim switches on the left (to the PIC) control wheel horn (Fig. 164). The switches are controlled with the left thumb.

Fig. 164. The view of the B737 stab trim switches

As to the RRJ-95 aircraft it is the priority pushbutton on the sidestick is under the PIC's left thumb (Fig. 165), and the manual trim in pitch is done with the switches on the cockpit central pedestal trim control panel (Fig. 166), which the PIC controls with the right hand.

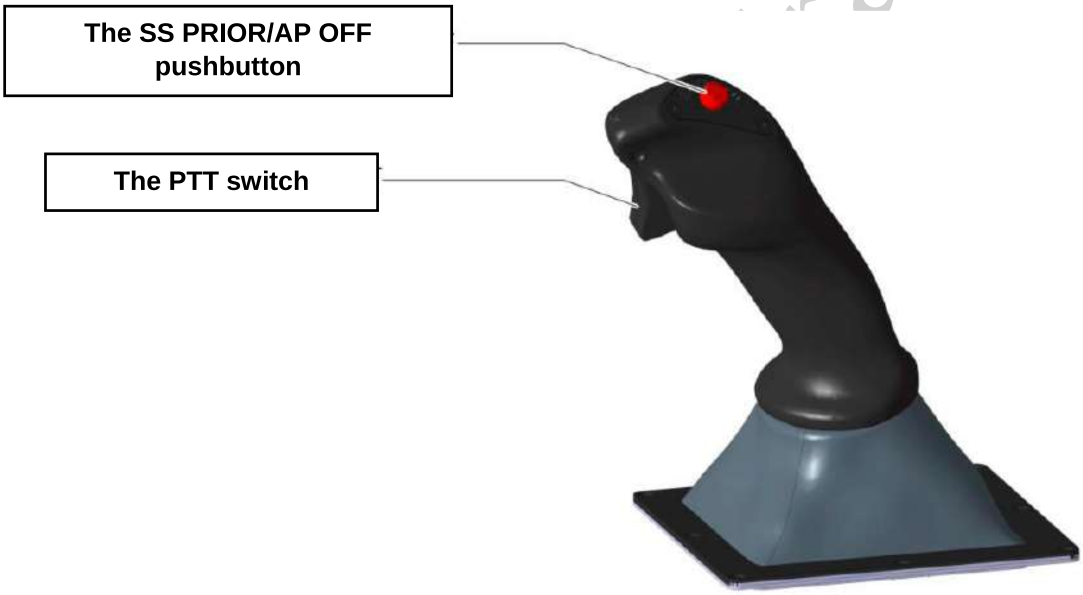
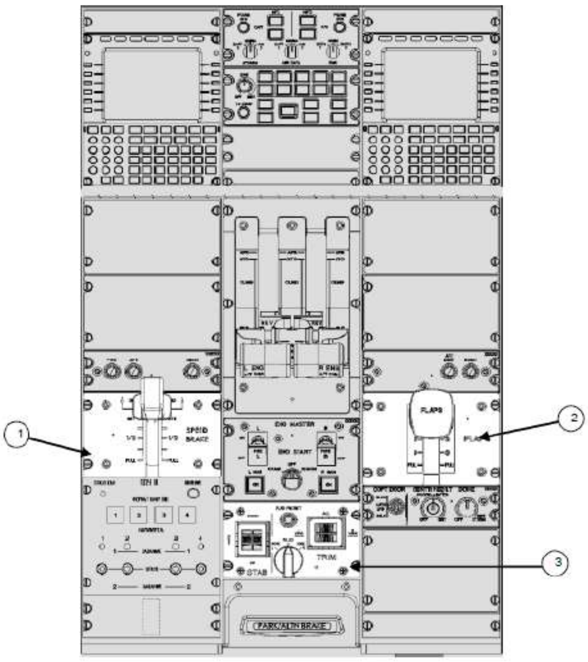
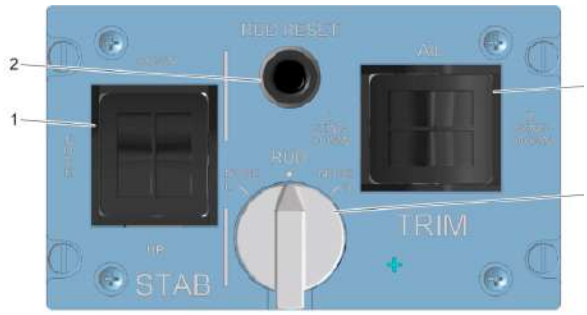


Fig. 165. The exterior of the RRJ-95 sidestick (the flight direction on the Figure is right to left)



1 Панель управления SPEED BRAKE
2 Панель управления FLAPS и SLATS
3 Пульт триммирования



1 Сдвоенный нажимной переключатель STAB управления стабилизатором
NOSE UP : создается кабрирующий момент самолета
NOSE DOWN : создается пикирующий момент самолета

2 Кнопка RUD RESET
нажатие на кнопку обнуляет сигнал триммирования руля направления

3 Сдвоенный нажимной переключатель AIL управления триммированием элеронов
L WING DOWN : создается момент на создание левого крена
R WING DOWN : создается момент на создание правого крена

4 Поворотный переключатель RUD управления триммированием руля направления
Для поворота переключателя необходимо на него нажать. Переключатель RUD поворачивать уверенно, не допуская малых отклонений около нейтрального положения переключателя. Величина отклонения руля направления по сигналу триммирования зависит от времени, а не от величины отклонения переключателя RUD.
NOSE L : создается момент на отклонение самолета влево
NOSE R : создается момент на отклонение самолета вправо

Fig. 166. The RRJ-95 central pedestal and trim control panel

This way, the stabilizer control to the previous types, operated by the PIC, and to the RRJ-95 is fundamentally different. As for the previous types, taking into account the «convenient» installation of the stabilizer controls «under the finger» and the fact that the stabilizer may be manually trimmed several times in the progress of every flight, the skill is established at the pilot of the instinctive (reflex) control by the concept: ***I feel pressure on the control column (discomfort) – I release it by pressing the switches***.

At the RRJ-95 aircraft (as well as at the number of other aircraft that integrate the full-scale auto trim function, for instance the A320 family) the vast majority of pilots throughout the flight career may not have to manually trim in real flight. The application of stabilizer to these aircraft requires conscious, but not the reflex actions. In DIRECT MODE the pilot is to first «identify» (determine) that the trim should be applied (as for the NORMAL MODE this skill is not established as the trim is continuously carried out for him by the FBWCS), further on, each time when the stabilizer should be used it is necessary to glance at the switches before allocating the right hand on them thereby distracting from the piloting (the instruments). Similarly at the stabilizer operation the pilot has to take the hand off the TL, which are controlled manually as well.

The differences in question entail in the necessity of the detailed explanation of the theoretical features of the trim at the type transition and scheduled recurrent training, whereas the practical skills should be imparted and checked as well as a part of the simulator sessions. At that the practical skills of trim should be mastered at every stage of the flight, as the amount of the potential retrim is significantly different as per the flight stages. The analysis of the airline transition training program theoretical segment content had been the evidence that apart of the mention that the manual trim should be applied in DIRECT MODE, there is no further information to focus on this issue. As stated in Section 2.2.1, due to lack of practice of detailed documenting of the pilots' recurrent training results in the airline it has not been possible for the investigation team to assess the actual amount of the PIC and F/O's training at the FBWCS operation in DIRECT MODE. At that, in view of the difficulties with the aircraft trim that the PIC had experienced into the flight that ended up with the accident against no comments at all by the flight instructors on the subject issue at the recurrent training and checks (see Section 1.5.1 of the Report), the issues of the air operations in DIRECT MODE may have received insufficient attention. Proceeding from the PIC's actions into the flight that ended up with the accident and the analysis of the flights in DIRECT MODE by the other airline flight crews more than likely at the pilots' training the necessity of trim was emphasized (highlighted) at the aircraft configuration change only. The pilots to the airline, including the PIC, had not have sustainable skills of the aircraft trim at the change of airspeed and/or power rating to the engines[150].

Into the investigation the airline representatives expressed the stand as follows: *«… the operational documentation does not integrate any methods for this trim. At this aircraft type mastering training for the instructors the manufacturer had not pay particular attention to this mode. Eventually the simulator training does not establish the sustainable piloting skill in DIRECT MODE»*. Indeed, apart from mentioning that one should manually trim the airplane (see Section 1.18.4 of the Report), the aircraft designer documentation does not state any method guidance. Nevertheless the RRJ-95B is not a primary training aircraft. The pilots, who are going to operate this airplane, should have basic skills and master the common principles of the air operations performance aboard the large transport aircraft. Among these basic skills is the understanding when the airplane should be trimmed and the awareness of this procedure importance to ensure the required precision of the manual operation. With that, according to the AR-25 Section «Flight Manual» item 25.1585 «The aircraft operation procedures», *«… (b) The information or procedures that do not deal with the airworthiness or these that cannot be applied by the crew should not be included, the procedures considered the basic airmanship should not be incorporated either»*.

Note: *Similar provisions are set out in the foreign airworthiness standards and the lead aircraft designers share alike attitudes (see for instance Section 2.2 of the Final*

[150] The similar weaknesses had been identified at the pilots to the other airlines, operating the aircraft with the sidestick (see, for instance, the Final Report on the results of the air accident investigation to the A321-231 VQ-BRS aircraft, occurred on January 10, 2020 at Antalya airport, the Republic of Turkey: https://mak-iac.org/upload/iblock/155/zuhp3s3lbx2rsut0lts2aqkukqmz8kr5/report_vq-brs.pdf).

Report on the results of the fatal air accident investigation to the B737 aircraft at Rostov-on-Don airport on March 19, 2016: https://mak-iac.org/upload/iblock/ab7/report_a6-fdn_rus.pdf).

Both at the post-accident interview and further on in the course of the investigation the PIC complained of the aircraft controllability in the pitch channel. As per his explanation: *«… after the transition to the level flight it had been very difficult to maintain the airplane. The airplane nose kept dipping. I tried to trim but did not achieve the desired result»*. In the light of the stated above the PIC's claims on the aircraft controllability are not validated by the hard evidence. The issue with «the nose dipping» had been totally due to the out-of-trim condition of the aircraft and the intermittent sidestick pressure release by the PIC (its return to neutral) with no trim (the stabilizer resetting).

The analysis of the flight evaluation by the test pilots and the outcome of the works, performed on the simulator in the course of the investigation suggests that the precision of the aircraft trim in pitch channel significantly affects the piloting quality, especially at the tasks of the precise piloting at the large gains, in other words at the significant sidestick deflection. The performance of the «pitch hold» modes on the simulator had been the evidence that at the original out-of-trim condition of the aircraft the time and the labor intensity of addressing the task is significantly increased, so is the oscillatory nature of the transient processes, there appears the necessity of the additional alternating sidestick inputs.

To analyze the PIC's piloting technique at the return to the departure aerodrome we will review the way of his performance of the turns, as this maneuver commonly implies the control inputs in all three channels (the pitch, roll, yaw) and the thrust control as well.

The time interval of 15:07:00 – 15:09:30 (Fig. 167)

Into this early interval (before the airplane had encountered the atmospheric electricity) the flight had been all through proceeded in the automatic mode. Into the climb it had been the right turn performed. At that:

- the stabilizer had been resetting, ensuring the auto pitch trim;
- the rudder had been automatically deflected to the right (at the neutral position of the pedals), enabling the coordinated turn (the sideslip and lateral acceleration close to zero);
- the A/T maintained the target airspeed of about 250 kt.

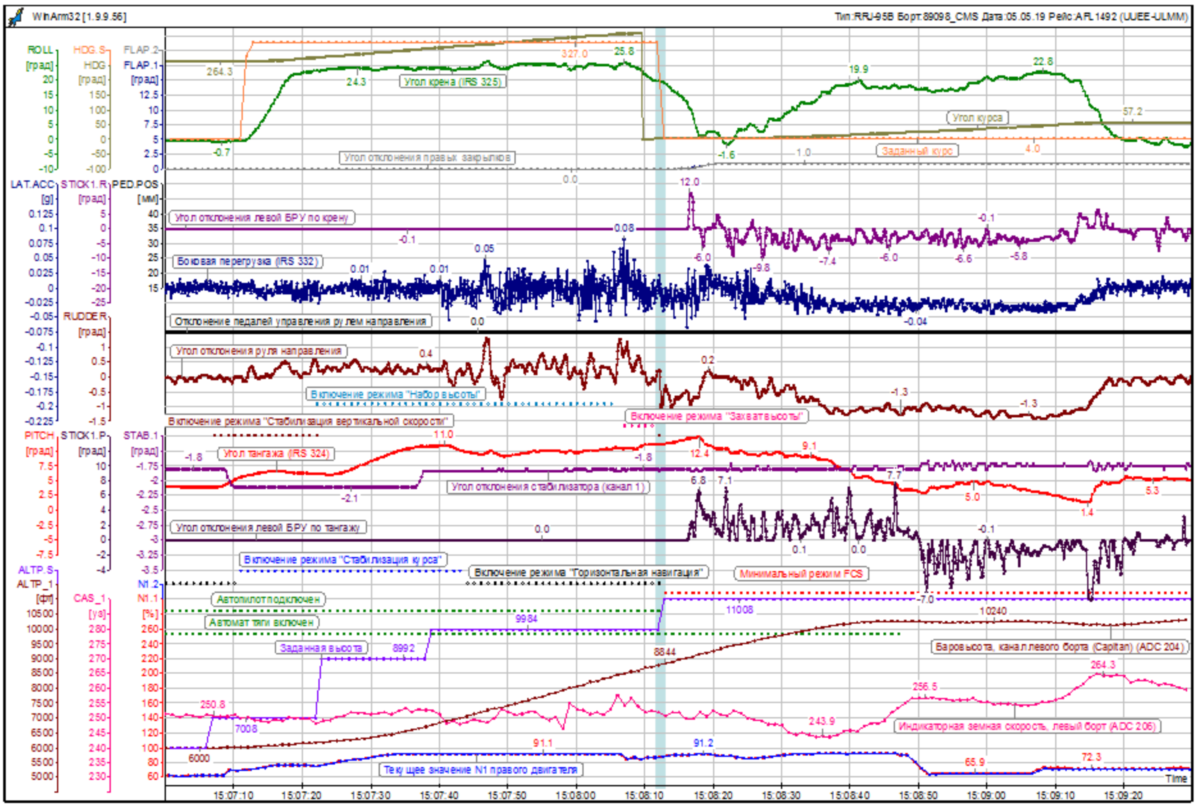


Fig. 167. The flight data into the time interval of 15:07:00 – 15:09:30 (the vertical line highlights the point of the aircraft encounter the atmospheric electricity)

To assess the PIC's control inputs after the aircraft encountered the atmospheric electricity and it was the transition to the manual control it should be understood what flight parameters he had tried to maintain. The analysis of the crewmembers' communication and the further proceeding of the flight shows that most probably after the aircraft exposure to the atmospheric electricity the piloting was aimed to proceed the right turn to follow the KN 24E SID and transit the aircraft in the level flight. With that the aircraft had been actually transitioned into level flight at the QNH altitude of 10200 ft. approximately (3109 m), which is below the FL, ordered by the ATC officer (FL110).

The analysis of the piloting in the roll channel after the transition to manual control is the evidence that it had been very «cautious» («hesitant»), as if with the «probing» of the aircraft response. It took the PIC 15-16 sec. and more than 10 sidestick «impulses» in roll by the amount up to the half of the available deflection to establish the right roll of the amount of about 20°. After the majority of the impulses the sidestick was returned to neutral, which is consistent with the method of piloting in NORMAL MODE at the operative function of the attained roll stabilization. As the automatic maintenance of the roll and coordinated turn are not enabled in DIRECT MODE, and the PIC did not apply pedals to eliminate the slip (with that due to the operation of the yaw damper the rudder deflected to the left), in other words, under the sideslip to the right and the spiral stability of the aircraft, after each sidestick release in roll to neutral the decrease of the roll was induced. By the second segment of the turn the PIC less often applied the return of the sidestick to neutral, keeping it deflected to the right, which enabled the maintenance of the relatively constant roll, even with the present sideslip, that is to say to a certain extent the PIC adjusted to the environment, still most advantageous decision might have been the application of pedals (these to the rudder) for the sideslip elimination.

Note: *The investigation team points out that the skills of the performance of the constant-roll and coordinated turns, as well as the skills of the aircraft manual trim in pitch apply to the basic airmanship. Meanwhile, similar to the pitch trim, the RRJ-95 pilots over the entire flying experience may never run into the situation, when this skill may be required, as in NORMAL MODE the maintenance of the roll and the turn coordination are accomplished automatically. At that the QRH F/CTL DIRECT MODE abnormal procedure does not integrate the recommendations on the turn coordination. The analysis of the flight in DIRECT MODE, performed by the test pilots, showed that in most cases at maintaining the constant roll the sidestick had been kept deflected, at that in certain cases the pedals had been applied as well (see Section 1.18.19 of the Report for details).*

In reviewing the sidestick inputs in pitch at the subject stage it can be noticed that the PIC's control inputs had been attributable to the «sustainable» skill of the manual operation in NORMAL MODE, when the sidestick pressure after its deflection and the establishment of the required pitch attitude was released and the sidestick returned to neutral. The maximum sidestick inputs in pitch amounted to the slightly over half of travel. As after the transition to DIRECT MODE the flaps had been automatically – as per the design integrated logic – repositioned to 1°, and the PIC did not trim the stabilizer manually, then due to the aircraft out-of-trim condition at the return of the sidestick to neutral, as in the case of the roll, the pitch attitude started to decrease (see the time interval of 15:09:00 – 15:09:15 on Fig. 167, for instance).

Generally, as far as the performance of this flight is concerned, it may be concluded that the PIC had been likely to feel uncomfortable at the manual piloting, but tried to adjust to the control in DIRECT MODE. At that he did not resorted to the stab manual control to trim the airplane in pitch and the pressing of pedals to coordinate turns that resulted in the necessity to keep the sidestick constantly deflected both in pitch and in roll, in the increase of workload (inter alia because of the elevated control over the aircraft attitude) and had been «unusual» against the operation in NORMAL MODE, that is to say it required reflection (and not just the motor actions) and the rejection of the steady «motor patterns» (the habitual control actions by the sidestick).

The mentioned factors degraded the piloting quality, indeed at that stage it had not been the task to the PIC to maintain the flight parameters very precisely.

The time interval of 15:12:40 – 15:16:15 (Fig. 168)

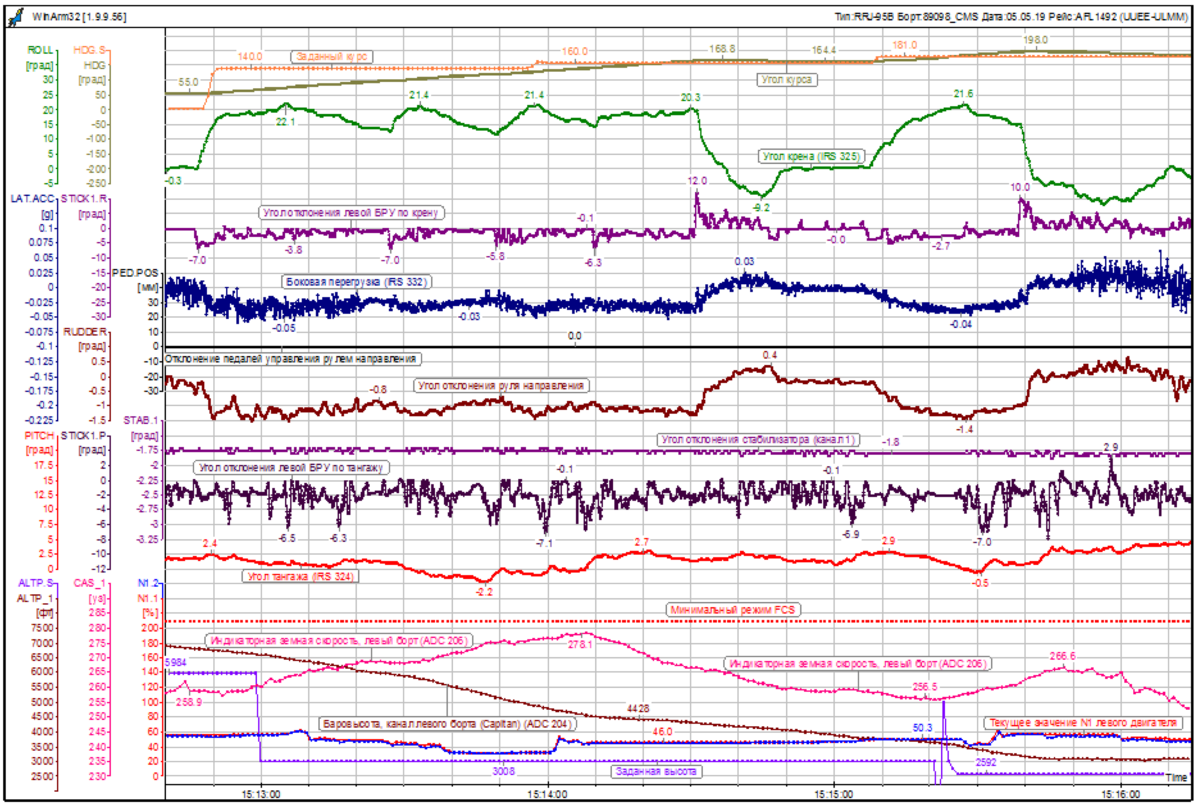


Fig. 168. The flight data into the time interval of 15:12:40 – 15:16:15

At this very stage the PIC was solving the task of the airplane track out from the heading of 55° to this of 180° (the controller successively instructed to establish on heading of 140° (at 15:12:43), 160° (at 15:13:51) and 180° (at 15:15:05) and to descend first to the QFE altitude of 900 m (the controller's instruction at 15:12:43), and then – to 600 m (the controller's instruction at 15:15:05).

Note: *The airline performs flights by QNH. Subject to the aerodrome elevation, the respective QNH altitudes were equal to: ≈ 3600 ft. and ≈ 2600 ft. At that at the setting of the altitude of 900 m QFE the crew made an error by setting the value of 3008 ft. (Fig. 168) with no account for aerodrome elevation. This fact, most probably, is indicative of the non-optimal psychoemotional condition of the crew. Further on it had been the correct setting of the QNH altitude, corresponding to 600 m QFE, by the crew.*

On the controller's order to perform the right turn the PIC with a quite firm sidestick input in roll up to 7° (less than half-travel) entered the aircraft in the right turn with the roll of ≈ 20°. However, as previously, the PIC did not use pedals to coordinate the turn. Eventually at the sidestick return in roll to neutral the roll decreased three times from the values of 20°– 22° down to 11°– 14°, the PIC thereafter adjusted it to the initial values. It should be noted as well that the target headings were captured with «the overshoot», which required the performance of the corrective additional turns to the left with the roll of ≈ 10°.

As within the previous discussed interval, the manual trim was not applied in the pitch channel, the airplane was trimmed with the residual back pressure. The engines power rating was changing between 31 % and 55 % N_1, along with that the IAS was changing within 258 – 278 kt (478 – 515 km/h). The descent was proceeded in the alternating profile, the vertical rate of descent was changing over a wide range from ≈ 300 ft./min (1.5 m/s) to ≈ 2500 ft./min (12.7 m/s), the flight path angle was between 0.7° - 5.2° to nose-down, the pitch attitude was changing from 2.2° to nose-down to 2.9° to nose-up. At the end of the stage the airplane was levelled to a horizontal flight at the altitude of ≈ 3080 ft. (939 m) QNH, which exceeded the value, ordered by the controller for almost 500 ft. (152 m) and approached the target altitude of 3008 ft., having been inaccurately set earlier.

In total, summarizing the flight stage under discussion, it may be concluded that the PIC became more confident in controlling the airplane in roll, the required rolls were established with higher precision and in less time. Still the PIC, apparently, did not analyze and did not grasp the causes of the constant «wandering» of the roll and pitch values. As on the previous stage both the aircraft control and trim had been ensured by the sidestick, the stabilizer and rudder (the pedals) were not engaged. At the «fight» with the roll and pitch the maintenance of the other parameters, most possibly less important to the PIC on this stage was ensured over a broad range.

The time interval of 15:16:45 – 15:19:30 (Fig. 169)

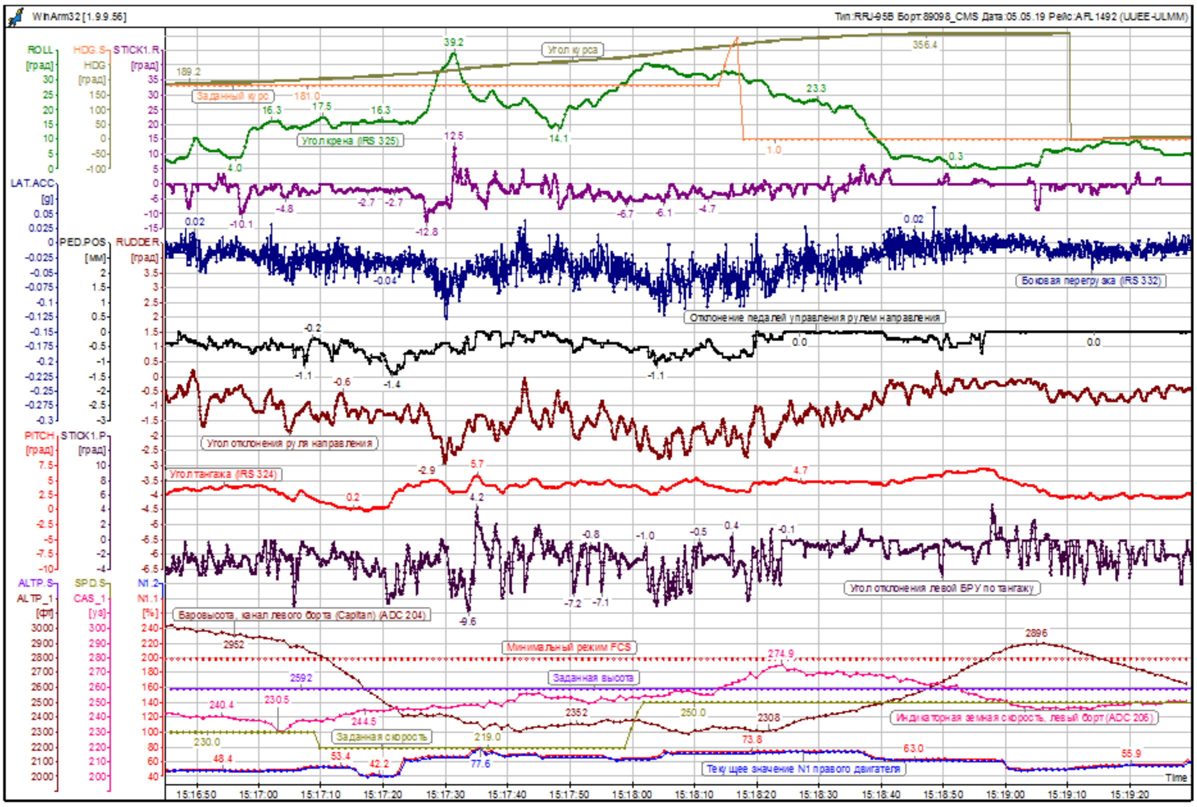


Fig. 169. The flight data into the time interval of 15:16:45 – 15:19:30

At this early interval the airplane was completing the descent down to the altitude of 600 m QFE, earlier ordered by the ATC officer at the IAS of 245 kt (454 km/h). At 15:16:55 the crew was instructed by the ATC to turn right to the heading of 210°. The current flight heading was about 190°. After being relayed of this ATC officer's instruction the crew did not reset the target heading value, although this action had not been skipped before[151]. Presumably, the PIC was totally focused on operating the aircraft, and the F/O was concentrated on the reading on the F/CTL DIRECT MODE QRH Section, that's what he was doing at the time.

After having been instructed to turn the PIC with a quite firm input entered the airplane in the right roll of 15° approximately. At this stage the larger amount of roll had not been required against the slight change of heading. To maintain the constant roll at the sideslip uncompensated the PIC retained little sidestick pressure.

In contrast to the previous reviewed stages at this one the deflection of pedals is recorded. As to the FDR record it is impossible to definitely determine who exactly of the pilots deflected pedals. However, based on the analysis of all the available information most likely it was the PIC. It was a slight pressure of the pedals within 2 mm (at full travel in one direction of ≈ 73 mm), but the deflections were changing and carried out continuously (that is to say the feet pressure against

[151] As from 15:18:17, at the subsequent instructions by the ATC officer, the crew went on changing the values of the target heading.

the pedals had been constant with the alternating force). At that it was the left pedal to be deflected forward, which additionally, however little, led to the increase of the sideslip angle, complicating the maintenance of roll. By the assumption that the deflection of the pedals by the PIC was conscious – to coordinate the turn – then this deflection was «in the wrong direction». With the substantial past experience of the PIC's operations of the airplanes without the function of the automatic turn coordination this error seems quite unlikely.

Given the slightness of the pedals deflection and its nature (not associated with the deliberate conscious control input), it may be explained as follows. The practice of air accident investigation is the evidence that when the pilots are in a non-optimal psychoemotional condition and begin to lose the situational awareness (there occurs the fragmentation of the flight image), they often make the involuntary (reflex) control inputs. At that, if these control inputs do not result in the noticeable change of the flight parameters, they are not monitored, and the fact of the inputs of the kind is not apprehended by the pilots. In the perspective in question as to the modern transport aircraft the most typical feature is the deflection of pedals that are not commonly used in flight. In the subject event the deflection of pedals is indicative of the non-optimal psychoemotional condition of the PIC, in other words the sign of the onset of his psychological incapacitation[152].

When approaching the target altitude the PIC was late to initiate the increase of the engines power rating and pitch attitude that resulted in the «overshoot» below it and the airspeed decrease down to 230 kt (426 km/h). The PIC at 15:17:23 responded to it saying: *«What's wrong»*.

The stage in question was actually the first after the FBWCS reversion to DIRECT MODE, at which the PIC with the high precision should have maintained the parameters both of the pitch (the constant aircraft altitude and speed control) and lateral motion (the interception of the target heading). The performance of this task had been quite complicated for the PIC.

At 15:17:26.5, at the current roll of ≈ 18° to the right, there was a steep sidestick input in roll to the right as well (up to 12.8° against the full available travel of 17.6°) with the subsequent keeping retained in the position of about 6° to the right that led to the onset of the roll angular rate up to 8.5 deg/sec. This control input resulted in the increase of the right roll up to the value of 39° in 5 sec.

This sidestick input cannot be explained in terms of the fulfillment of the current piloting task. The current heading was ≈ 225°, that is the airplane had already crossed the heading, ordered by the controller (210°), and there were no further instructions relayed to the crew to continue the

[152] See the Final Report on the results of the investigation of the fatal air accident to the B737 aircraft at Rostov-on-Don airport on March 19, 2016 as well: https://mak-iac.org/upload/iblock/ab7/report_a6-fdn_rus.pdf.

turn. It is probable that amid «the struggle with the altitude» there had been a short-term PIC's spatial disorientation that induced the sidestick input «in the wrong direction», while attempting to level the airplane out of the roll. This is another evidence of the PIC's non-optimal psychoemotional condition.

At 15:17:29 the PIC uttered: «*We should proceed by circuit. We are not ready for approach»,* this was followed by the sharp sidestick input in roll to the left up to the amount of 12.2°. The further sidestick control inputs in roll resulted in the stabilization of the roll at the values of 20°– 25° to the right, that is to say the airplane continued to turn right, significantly deviating off the heading, ordered by the ATC officer[153].

Into this maneuvering the aircraft kept descending that is further departed off the target altitude. At 15:17:32 it was a standard altitude alerting system trigger. As per the design integrated logic this alert triggers at the deviation of the pressure altitude current value off the target one for the amount of more than ± 200 ft.

At 15:17:36 the PIC uttered once again: *«We are not ready for approach, we should proceed by circuit»*. The PIC's decisions at this stage show that, although he was in an apparently non-optimal psychoemotional condition, he did not lose the ability to critically perceive the flight environment.

At 15:18:14 the controller requested: *«… how soon will you be ready for approach? »,* to which the PIC instructed the F/O to reply that they would be ready in 10 minutes. Still, he immediately tried to contact the ATC officer himself and requested a holding spot over «KILO NOVEMBER». The PIC's decision not to attempt the approach «right away» was appropriate and substantiated.

Note: *At the request to the ATC officer the PIC used the «holding spot» word combination. The flight environment was rather tense and not conducive to the use of «diminutives». It appears that the use of this term indicates the non-optimal psychoemotional condition of the PIC, having been his attempt to handle this condition by psychologically «simplifying» the situation, which is consistent with the results of the examination of the PIC's psychological profile (see Section 1.16.21 of the Report).*

The ATC officer did not respond to the holding area request (see Sections 1.18.25 and 2.4 of the Report as well). The PIC did not repeat the request, which is again indicative of the non-optimal psychoemotional condition and «hopping» from one task to another, as right there the PIC commanded the F/O to continue reading the QRH Section.

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[153] It is not earlier than at 15:17:45, after the crew requested orbit, the controller instructed to establish on the heading of 360°.

Note: *The investigation team points out that at the radio communication on the emergency frequency without the monitoring of the main frequency the aircraft flight crews should be aware that their requests may overlap the requests by the other crews on the main frequency that is possible to result with their «skip» by the controller. This is the irremovable hazard into the radio communication on the emergency frequency. It is with only another relay of request, which had not been responded, that the mitigation (monitoring) of the associated risk (when the monitoring of the main frequency is not ensured) is possible.*

The investigation team indicates that at this stage, perhaps, the PIC should have taken the aircraft control over to the F/O to calm down, reflect on the situation and make plan for the next steps. There had been no new issues to the aviation equipment. The radio communication was resumed. As the decision to return was made hastily at the substantial uncertainty on the condition of the aviation equipment, on this stage the performance of the comprehensive before landing briefing, the clear distribution of responsibilities, drafting of the further actions plan, including at the potential go-around, would have been the PIC's wise decision. Nothing of these had been done.

Note: *As indicated in Section 1.5.1 of the Report at the scheduled drills and checks the PIC had been several times commented by the instructors on the «formal» and «ill-considered» performance of the briefings and checklists. The PIC, probably, underestimated the significance of these elements and their effect on the aviation safety.*

Meanwhile the PIC tried unsuccessfully to bring the airplane to the target altitude. The PIC's control inputs in pitch altered its value within the range of 3°– 6° to nose-up, which, against the considerable roll, was insufficient to transition the airplane into climb. The altitude alert was kept triggered. Along with that the IAS increased up to 275 kt (509 km/h).

At that point of time the aircraft was approaching the target heading (360°) and the PIC initiated the level out of the roll. As the roll was decreasing, the aircraft transitioned to climb. At the approach to the target altitude the altitude alert silenced. The total duration of the system operation at this stage amounted to 57 seconds.

The level out of the airplane and the excessive pitch attitude (AOA) for that environment at no corrective inputs by the PIC resulted in the «overshoot» of the target altitude upwards this time and another trigger of the altitude alert (for 18 sec.). At that the IAS returned to the value of 245 kt (454 km/h).

Further on the airplane continued to be flown along «the orbit», and the PIC went on with his unsuccessful attempts to maintain the target altitude of the flight. The deviations off the target altitude generally occurred at the establishment of the significant rolls (more than 15°). The altitude alert was activated several more times with a various duration. Another altitude alert activation provoked the PIC's «frustration» (annoyance) and he spoke it out (at 15:22:53: *« What's wrong. Plus-minus 200 feet»*).

Likewise the PIC continued to experience difficulties with the maintenance of the constant roll in turns. Being distracted by the alert activation and the maintenance of the flight altitude the PIC released the pressure on the sidestick in roll, which induced the roll decrease. At keeping the sidestick deflected in roll the PIC's piloting quality in the pitch channel was disrupted, causing the inability to hold the required pitch and ensure the maintenance of the flight altitude.

It is also noteworthy that the crew reset the values of the target speed several times (Fig. 169). It had not been possible to identify who and for what purpose did this, since no commands or acknowledgment of changing the set values were recorded by the CVR.

Summing up this stage of the flight, based on the conclusion by the test pilots, stated here above, that as for the trimmed aircraft in DIRECT MODE, the maintenance of the IAS in the range of ± 5 kt (10 km/h) and the altitude of ± 100 ft. (30 m) does not induce a significant load of the pilot, the investigation team comes to the conclusion on the PIC's piloting quality, having been unsatisfactory for a long time and on his inability to maintain the required flight parameters. At that throughout the reviewed stage and up to the end of flight the PIC kept deflecting the left pedal incrementally. These inputs had not been contingent with the current flight environment, and, as previously, had been reflex (unconscious) by nature.

The performance of the QRH procedures

The procedure for performance of the abnormal and emergency procedures is stipulated by the FCOM Section 1.08.10 and OM Part B Chapter 4. Both documents integrate essentially similar provisions. At that the OM Section 4.1 «GENERAL» reads the sentence as follows: *«If the Aeroflot, PJSC standards are different, then the procedures that shall be carried out are stated in this document. Anyway, the requirements of this document predominate the others».*

In the OM Section 4.1 it is noted that *«The abnormal and nonstandard[154] procedures include the actions that the flight crew shall take to achieve the required level of airworthiness to safely proceed the flight and landing».* This implies that the timely and good-quality (comprehensive) performance of the subject procedures directly affects the airworthiness and flight safety.

The distribution (compliant to the OM) of the PF and PNF responsibilities as far as the performance of the emergency procedures is concerned is given in the Table here below.

[154] Instead of the «emergency procedures» term, applied in the FCOM, the OM reads the «nonstandard procedures» term (similarly to the foreign-manufactured aircraft types). Hereinafter through the text of the Report these terms are used interchangeably (as synonyms). As stated by the aircraft designer the airline submitted multiple requests on the harmonization of documentation to the RRJ-95 with this to the A320 aircraft family that generally does not always seem reasonable.

Пилотирующий пилот (PF)	Непилотирующий пилот (PNF)
- установка рычагов управления двигателей; - траектория полета и управление скоростью; - навигация (самолетовождение); - ведение радиосвязи; - подача команды на выполнение карт контрольных проверок и изменение конфигурации ВС (если необходимо); - подача команд на начало и приостановку выполнения процедур QRH; - взаимодействие с кабинным экипажем CM1	- выполнение действий по QRH либо по памяти; - чтение карт контрольных проверок / правильность ответов по картам контрольных проверок; - выполнение команд на изменение конфигурации ВС; - эксплуатация по согласованию с PF переключателей ENG MASTER, IRS, ADS и органов управления, закрытых защитной рамкой

PF	PNF
– the setting of the TL; **– the flight path and the control of the airspeed;** **– the navigation (the airplane operation);** **– the conduct of radio communication;** **– the issue of commands to do checklists and the change of the airplane configuration, when required;** **– the issue of commands to initiate or interrupt the doing of the QRH procedures** **– the interaction of CM1 with the cabin crew.**	**– the performance of the actions by QRH or the memory items;** **– the reading of checklists/the correctness of answers by the checklists;** **– the execution of commands to change the airplane configuration;** **– in coordination with the PF the operation of the ENG MASTER, IRS, ADS switches and the controls, secured by the guard**

Into the descent, at 15:13:11, the PIC commanded the F/O to do the F/CTL DIRECT MODE QRH Section (it is attributed to the abnormal procedures). The F/CTL DIRECT MODE is not a memory item, that is to say the crew shall carry it out on a READ – DO principle.

At 15:13:42 the F/O started to read and do the AUTO FLT AP OFF QRH Section that belongs to the emergency procedures and not to the abnormal ones and is carried out as well on a

READ-DO principle. It is probable that the F/O started this section because the associated message was displayed first on the EWD (the F/CTL DIRECT MODE message was displayed the second, see Section 1.16.3 of the Report as well).

The investigation team points out the inconsistency of the crewmembers' actions. On the one hand it is the F/CTL DIRECT MODE QRH Section that the PIC commanded to do, that is to say the F/O initiated the doing of another Section by mistake and at that stage the PIC did not correct him. On the other hand the Section that the F/O started to do was attributed to the emergency procedures and was displayed first on EWD. It made sense to start doing the emergency and abnormal procedures with it, still the F/O did not prompt it to the PIC and «corrected the error» in the selection of the Section on his own.

The actions by the AUTO FLT AP OFF QRH Section consist of two items (THE AP PUSHBUTTON ON THE FCP – PRESS; IF AP DID NOT ENGAGE – OPERATE AIRPLANE MANUALLY). The F/O read and did the first item, the AP did not reengage (it is consistent with the design integrated logic), at that the associated sound warning was generated.

At 15:13:51 the ATC officer called the crew with the request. Contrary to the OM provisions, stated here above, it was the F/O to enable the radio contact with the controller, being distracted from reading QRH. The radio session lasted till 15:14:11.

Note: *At the post-accident interview the PIC explained that he asked the F/O to conduct the radio communication, as it had been unstable[155] and its conduct involved the distraction from the manual control. The CVR had not recorded this command or request by the PIC.*

After the radio communication session was over the F/O once again started the doing of the AUTO FLT AP OFF QRH Section. Once again the AP did not engage. After the reading of the second item of the Section the PIC corrected the F/O and requested once again to do the F/CTL DIRECT MODE Section.

After that it had been a pause. The F/O may have been busy, getting prepared for the performance of the required procedure.

At 15:15:05 the ATC officer established the contact with the crew with the instruction to descend to the altitude of 600 m QFE. It was the F/O again who conducted the radio communication. The communication session was over at 15:15:44.

At 15:15:45 the F/O started reading the F/CTL DIRECT MODE QRH Section (see Section 1.18.4 of the Report). The reading had lasted continuously till 15:16:51, upon which the PIC interrupted the F/O, instructing him to call the controller. The investigation team observes that in

[155] The analysis of the radio communication quality is addressed in Section 1.18.26 of the Report.

this case the PIC allowed the violation of two OM provisions at once: the conduct of the radio communication at the reading of QRH was up to him and at the interruption of the Section reading it should have been a STOP CHECKLIST command given, which had not been issued. After the communication session with the controller the F/O by 15:17:22 had completed the Section reading, the CONTINUE CHECKLIST command, stipulated by the OM, was not issued either.

The investigation team points out that the reading was done hastily. There were no comments by the PIC or the discussion on what had been read either through the reading of the Section, or at the reading of «the statuses» (the systems under failure), or at the completion of reading.

At 15:19:11 the F/O asked the PIC if he should do the OVERWEIGHT LANDING QRH Section (it is attributed as the abnormal procedure and not displayed on EWD, see Section 1.18.5 of the Report). The PIC replied affirmative. This procedure is similarly done on a READ-DO principle.

Note: *The analysis of the CVR record was the evidence that the flight crew did not look into the option of the fuel burnoff to decrease the landing weight.*

The F/O started doing the Section at 15:19:15.

At 15:19:38 the ATC officer once again established the radio contact with the crew, the F/O interrupted the Section reading to conduct the radio communication. After the communication session was over the PIC instructed the F/O to start up the APU and the activation of the new route in the FMS. Then it was another communication session with the controller.

It was just at 15:21:20 after the APU was started up that the doing of the QRH Section was continued. The PIC at 15:21:35 once again interrupted the doing of the QRH Section with the command to extend flaps, over again the STOP CHECKLIST and the CONTINUE CHECKLIST commands were not issued.

After the check of the flaps extension the F/O at 15:21:42 continued the reading of the QRH Section, but was again interrupted with the controller's radio contact and the need to respond his request.

At 15:22:07 the reading of the Section was resumed and lasted till 15:22:49, when it was interrupted again by the PIC without giving any commands.

It is not earlier than at 15:23:09 that the F/O completed reading of the Section.

Similarly to the doing of the previous Section the reading was proceeded in «a rapid speech», on the completion of reading the essence of what was read had not been discussed by the crew.

In this way the QRH Sections reading totally amounted to 10 min. approximately. At the intense maneuvering at this stage of flight, the preparation of the aircraft systems for landing and the necessity to proceed radio communication with the ATC, having been concurrent, the doing of the subject Sections was done by the crew inconsistent with the OM provisions, mostly formally, in a haste, that could have contributed to the further increase of the psychoemotional tension and the narrowing of the flight image. The investigation team believes that the proceeding to the holding area and the thoughtful doing of the QRH Sections with the subsequent arrangement of the before landing briefing would have been the crew's intelligent decision. Even more so that the subject Sections integrated the various provisions on the calculating of the number of parameters to perform landing and application of the systems.

Note: *When two or more abnormal or emergency procedures are to be addressed, which may incorporate different provisions on the same issue, the operational documentation, generally, does not set priorities. In each particular case the decision is to be taken by the crew on the basis of the analysis of all the available information.*

As noted above, the PIC requested the holding area at the ATC, but was not responded and, having been overwhelmed «fighting» with the airplane at the maintenance of the target altitude, never returned to the issue. This fact may be indicative of the flight image narrowing at the PIC, when certain features, although important to its safe completion (and being eventually apprehended as such), but not arising from the current parameters of the flight (not interrelated with the solving of the current tasks) are skipped.

As a general conclusion the investigation team points out that there was no appropriate CRM on the part of the PIC. It is probable that as it stood then it had been a consequence of the PIC's insufficient human factor and threat and error management approach training[156].

2.2.5. The analysis of the operation by the crew at the aircraft final approach and landing

At 15:22:59 the ATC officer requested the crew if ready for approach. The crew responded that they are ready. It is worth noting that the PIC announced this decision (on having been ready) to the F/O without hesitation, without discussing it with him in a second after the controller's contact was over, as well as immediately affirmed it in response to the clarifying question by the F/O.

Note: *As mentioned in Section 1.5.1 one of the instructors' comments to the PIC in the progress of the training was that that he makes unilateral decisions, not taking into account the F/O's opinion.*

This decision was made by the PIC despite the ongoing challenge of maintaining the flight parameters (at that point the altitude alert was kept triggered). As compared with the flight stage when the PIC made the decision to proceed the flight by circuit (and even pronounced the intention

[156] The PIC's human factor and CRM training is set out in more detail in Section 1.5.1 of the Report.

to proceed to the holding area), the piloting quality issue had not been improved and the PIC was aware of this. The decision to initiate approach was probably arisen from the PIC’s desire to complete the flight, going on unfortunately, as fast as possible all the more so because the airplane was approaching the landing heading and the proceeding of another «orbit» would have significantly increased the flight time.

Note: *As stated in Section 1.16.21, the PIC’s personality traits inter alia featured the susceptibility to the passive-dependent behavior, the striving for avoidance of the non-success, the escape from solving problems, the potential constraints of the choice and decision-making.*

After the announcement of his decision to the F/O the PIC without the request by the ATC officer and getting his clearance right away entered the aircraft in the right turn to track it out to the landing heading, at that the crew did not set the landing heading value as the target one (the target heading value had remained 170° until the end of the flight).

The turn was performed with the roll of about 15°. To maintain it, at the current sideslip, the PIC continuously «steered» the sidestick in roll. Into the turn, as the airplane was descending, the altitude alert was once again triggered. The stop of the alert operation was associated with the aircraft level out of the roll, and, consequently, its transition into climb.

It was an early turn of the aircraft to the landing heading and it was positioned far to the right off the localizer equisignal zone. The PIC might have been aware of this, as virtually immediately without any callouts by the F/O, entered the aircraft in the left roll. The left additional turn was going on «sluggishly» with the roll of 5°– 7°. At 15:24:09 the controller drew the crew’s attention to the airplane deviation: *«Aeroflot 14-92, if you intend to establish on localizer, turn about 20 degrees left»*, the crew acknowledged this information right away and continued the left additional turn at the unchanged rate.

Into the left additional turn the landing configuration was set to the aircraft. Against all the shortcomings of the piloting, mentioned here above, the flight parameters and the aircraft configuration themselves at the approach to intercept the glideslope did not constitute significant risks to safety. By contrast the ensurance of the «acceptable» flight parameters in the subject environment more than likely «has come» to the PIC at a cost of the crucial increase of the psychoemotional tension, the runout of the reserve (the psychological one, first of all) and the narrowing of the flight image. Finally, most probably the psychological dominant for the prompt performance of landing had been established at the PIC. Among other things the PIC was not psychologically determined to reject approach and proceed with go-around that is to say he was not in a «go-around prepared» or «go-around minded» condition when the determinant logic is as follows: *«I am ready to go around in case of detecting any inconsistency of conditions to perform* *landing and will continue approach unless all parameters are normal»*. The non-arrangement of the before landing briefing, at which the go-around procedure is reviewed, the failure to set the altitude of the go-around initiation and landing heading speak in favor of this assumption.

Note: *The investigation team identified the violation neither of the flight crewmembers' duty and rest schedule, nor of the established standards to the flying time. By contrast the investigation team detected substantial irregularities in granting the flight crewmembers with the leaves (see Section 1.5.1 of the Report). The large number of unused days of the PIC's basic and additional leaves against the intensive involvement in air operations might have contributed to the accumulation of the chronic fatigue, the impaired performance and stress resistance, in other words to degrade his «psychological reliability».*

The investigation team indicates that at the investigation of a number of the air accidents to the heavy transport aircraft, occurred recently in the Russian Federation airlines, the substantial disruption of the flight personnel duty and rest schedule was observed, including the untimely granting the flight personnel with the leaves that constitute significant risks to the aviation safety. Notably, the disruption of the kind had been stated at the investigation of the following occurrences: the fatal air accident to the Aeroflot-Nord Boeing 737 in 2008, this to the Tatarstan airline Boeing 737 in 2013, to the Saratov Airlines An-148 in 2018, etc. The monitoring of this issue by the aviation authorities appears to be insufficient.

The CVR had not recorded any communication in the crew, relative to the glideslope target speed estimated value. At the top of the glideslope descent the value 155 kt (287 km/h) was set, which was consistent with the estimated value for the actual landing conditions. It has not been possible to determine who of the flight crewmembers performed this action. The CVR had not recorded any commands or checks to this action.

Note: *According to the information, submitted by the aircraft designer, at the test flights there had been no overweight landing performed in the FBWCS DIRECT MODE. Nevertheless based on the general principles of aerodynamics on condition of the maintenance of the set airspeeds on the glideslope there should be no noticeable differences in the landing performance technique.*

At 15:26:05 there was a discussion in the crew as follows: *F/O: «Shall I set the squawk of seven seven two zeros? Or I leave it as it is? OK, got it». PIC: «For good it could already be removed».* The CVR record does not allow a clear understanding of the PIC's decision. At 15:26:30 the crew set the 7700 squawk code. Meanwhile the crew conducted the radio communication with the Radar ATC officer, who handed it over to the Tower controller. The crew did not report the in-flight emergency (MAYDAY) either to the Radar controller, or to the Tower ATC officer (after the contact was established with him). The crew did not notify the flight attendants about it either for they could prepare the passenger cabin for the emergency landing (earlier in the conversation with the CFA the PIC emphasized that the landing would not be the emergency one). At the post-accident interview the PIC stated that the crew had set the 7700 squawk code due to the poor controllability of the aircraft (*« [we] set 7700 after the extension of the wing high-lift devices shortly before the glideslope interception in a horizontal flight in view of the fact that after the transition to the horizontal flight it had been very difficult to maintain the airplane) »*. As mentioned above, «the controllability issues» had been observed since the FBWCS reversion to DIRECT MODE and were derived from the out-of-trim condition of the aircraft, as well as the PIC's failure to ensure the precise maintenance of the flight parameters. Thus, due to the inconsistency of the available factual information, it has not been possible to assess the actions by the crew on the setting of the 7700 squawk code.

The approach had been the ILS one by the ILS raw data. Compliant to FCOM (Section 1.02.15 page 5), the RVR minimum for this system is 1000 m. The similar value is stated in the OM Part B (page 1.8.1). The actual weather conditions were appropriate to perform landing.

Into the glideslope flight the aircraft was not fully balanced (trimmed) in the pitch channel. To maintain the constant pitch attitude the continuous aft sidestick input was required by the amount of 2°– 3° (15 % of full travel approximately). Like before the PIC on completion of the control input released the sidestick pressure and it returned to neutral. Meanwhile the airplane nose dipped that resulted in the necessity of another back sidestick input to maintain the glideslope. As the result the aircraft was descending parallel to the established glideslope, below it for 0.5 -0.6 dot on average. That is to say, at this stage of the flight the lack of trim to the aircraft induced, as before, the increase of the PIC's workload, associated with the necessity to constantly monitor and correct the aircraft pitch attitude.

The airspeed by glideslope, maintained by the crew, was roughly consistent with the target value.

At 15:28:28 at the altitude of slightly over 1000 ft. (305 m) over the RWY 24L threshold it was the activation of W/S WARNING that is generated by the crew alerting system as per the weather radar windshear predictive (forecast) feature. The warning integrates the GO AROUND WINDSHEAR AHEAD sound warning and the indication of W/S AHEAD message of the red color on PFD. The total time of the warning trigger was more than 10 sec. The crew did not discuss the activation of this warning and did not respond to it.

At the post-accident interview the PIC explained that as the flight parameters had been in line with the stabilized approach criteria and the RWS system had been serviceable, he, in accordance with the operational documentation provisions, continued the approach.

Note: ***Over the record of interview of the PIC***

At the altitude of about 1100 ft. it had been the trigger of GO AROUND! WINDSHEAR AHEAD warning. The parameters were in line with these of the stabilized approach. The Reactive Windshear System had been in a serviceable condition and, compliant to QRH, we had the right to continue approach.

The W/S AHEAD QRH Section (see Section 1.18.6 of the Report) reads that at the activation of this warning at the approach leg the crew shall perform go-around. By contrast at the beginning of the Section there is a note that if the crew made sure that there is no threat of the windshear and/or the other signs of it and the RWS system is serviceable, then this warning trigger does not require any action. It is pointed out as well that at some airports there is a potential of the spurious activation of this warning because of the specific nature of terrain and obstacles. The airline OM incorporates similar provisions. Along with that as for the operational documentation «the other signs» examples are not indicated anywhere, on which the crew is to evaluate the accuracy of this warning activation. The investigation team points out as well that the RRJ-95 FCTM (Section 04.10 P. 19) integrates the provisions on a single-option go-around (it is the wording applied: *«In case the "GO AROUND WINDSHEAR AHEAD" message is triggered, the PF* ***must set TOGA***[157] *for go-around»*).

Note: *The provisions on the possibility to disregard this warning in similar conditions are stated in the Airbus operational documentation (for instance, to the A320 family). By contrast the operational documentation to the Boeing aircraft (for example, B737) integrates the unequivocal instruction on the single-option initiation of go-around.*

The principles, integrated in the PREDICTIVE WINDSHEAR warning operation logic, virtually assure the detection of the windshear, when present. At that the converse does not always hold true, that is to say the delivery of the respective warning does not always imply the certain presence of the windshear, that is there is a potential of the spurious activation.

At the point of the aircraft landing there had been the thunderstorm, adjacent to the aerodrome, the aircraft encountered atmospheric electricity in-flight, the moderate gusty wind had been observed (160°– 7 m/s, gusts 10 m/s), of which the crew had been briefed. The investigation team is of the opinion that the subject circumstances had suited well to the wording of *«the other signs of Windshear»*, that is it had been the PIC’s unreasonable decision to continue approach.

[157] It has been highlighted by the investigation team.

Note: *As per ICAO Annex 3 «Meteorological Service for International Air Navigation» Appendix 6 item 6.1 the windshear conditions are normally associated with the following phenomena:*

- *thunderstorms, microbursts;*
- *strong surface winds coupled with local topography.*

As the Sheremetyevo aerodrome RWY 24L is not troublesome in terms of the spurious activation of the mentioned warning and the information, available to the crew, had not ruled out the complex (as regards to the windshear) weather environment, the crew had had every reason «to confide in» the warning and make the decision to initiate go-around. The engineering simulation was the evidence that immediately prior to touchdown the aircraft encountered microburst (Section 1.16.22.4 of the Report) that had affected the aircraft motion path, and may have impacted the outcome of the flight (see below through the text).

The PIC's reference to the current «approach stabilized condition» as the criterion, applied to assess reliability of the PREDICTIVE WINDSHEAR warning, indicates his insufficient knowledge on the matter. The operational logic of the weather radar is that the warning on the potential presence of windshear is delivered in advance (at 10 – 60 seconds before the actual entrance). That is to say the approach stabilized condition «here and now» cannot reliably indicate that there is no windshear ahead. With that the warning generation depends on the location of the windshear phenomenon only, and not on its force. The data on the basic principles of the weather radar operation is stated in FCOM (Section 2.34.70 WEATHER RADAR) and FCTM (Section 04.60 USE OF RADAR).

Note: *As indicated in Section 1.5.1 of the Report, at the scheduled drills and checks the PIC, at least twice (on March 4, 2018 and August 30, 2018), had been commented by the instructors on the untimely identification of the windshear. Similarly on November 8, 2018 the instructor's comment is recorded on the «the lack of the wind information monitoring at takeoff and landing». Inherently the PIC may not have associated the windshear encounter with a serious threat to the safety of the flight.*

It is likely that the PIC's decision to disregard the windshear warning had been affected by the aforementioned psychological dominant to land and the reluctance to abort the approach. In the presence of a dominant goal and in a non-optimal psychoemotional state, the information (if it is not obvious and straightforward), which can impede the performance of the desired (the landing to this case), is not perceived and not taken into account (subconsciously repressed).

At 15:28:38 the TAWS auto callout sounded on the true altitude capture of 1000 ft. (305 m). After the activation of this alert the crew monitored the approach stabilized condition. The Aeroflot, PJSC OM Part B Chapter 2 Standard Operating Procedures, page 2.3.24 specifies that at the ILS approach at the altitude of 1000 ft. AAL the crew shall monitor the stabilized approach criteria. The stabilized approach criteria as per the FCOM and OM are stated in Sections 1.18.7 and 1.18.8 of the Report respectively. Compliant to the set out criteria, the approach had been stabilized[158]. The PIC made the substantiated decision to continue the approach, of which he notified the F/O by the callout: *«Continue»*, – to which the F/O responded: *«Check»*.

Note: *1. According to OM (PART B, Chapter 2. Standard Operating Procedures), at that stage of the approach the F/O should have reported the 1000 ft. altitude capture and the meeting of the stabilized approach criteria, and the PIC should have checked this information and notified of this with the CHECK standard callout or the decision should have been made by him on the initiation of go-around at approach, not stabilized. The PIC's report «Continue» is to be done before the DH[159] is reached. At that very stage the PIC should have made the decision to continue approach (and not initiate go-around) and announced it to the F/O.*

2. Compliant to OM, the approach stabilized condition is to be checked at the altitude of 1000 ft. QFE. Actually, the crew was checking it after the activation of 1000 ft. true altitude capture auto callout. Given the terrain height, the actual QFE altitude amounted to 900 ft. approximately. As far as the occurrence under discussion is concerned, this fact did not anyhow affect the outcome of the flight. Still, as for the flights to the aerodromes with the significant terrain alteration under the glideslope the failure to consider this factor may establish significant risks to the aviation safety.

Further on, it had been the increasing deviation of the airplane off the glideslope below it.

By the point of time of 15:28:45 at the altitude of about 800 ft. (240 m) QFE the deviation off the glideslope equisignal zone became more than 0.5 dot. As per the FCOM, the F/O should have reported this to the PIC. The similar provisions can be found in the airline OM. These actions had not been taken.

By the point of time of 15:28:55 at the altitude of about 670 ft. (244 m) QFE the deviation off the glideslope equisignal zone became more than one dot. As per the provisions of the Bulletin # B 05-19-RRJ-95 (the airline Flight Methodological Board Minutes of Meeting # 4-18 of December 20, 2018), the ILS approach shall be rejected, if at the altitudes below 1000 ft. AAL the equisignal

[158] The current deviation off the glideslope equisignal zone amounted to 0.4 dot.
[159] According to FCOM (Section 1.02.15 page 5), the decision height for the approach by the ILS raw data is 270 ft (80 m). The similar values are stated in the OM Part B (page 1.8.1).

zone deviation exceeds 1 dot. There had been no report by the F/O on the magnitude of the actual deviation, the crew had not discussed the option of go-around. Thus, the crew had not complied with the provisions of the subject Bulletin.

Note: *As mentioned in Section 1.5.1 of the Report, at the scheduled drills and checks the PIC had been commented by the instructors on «the lack of critical evaluation of the flight parameters in terms of «the stabilized approach» at the ILS approach».*

At 15:29:20 the DH was reached, to which the MINIMUM. MINIMUM auto callout triggered, called out by the F/O as well. Before that the F/O gave the standard callout on approaching the DH (APPROACHING MINIMUM). The current deviation off the glideslope was 0.9 dot. The PIC continued the approach, at that he had not uttered any additional information. The F/O did not report the aircraft deviation off the glideslope either.

At 15:29:36, in between the activation of the 200 ft. (60 m) and 100 ft. (30 m) altitudes capture TAWS auto callouts there was the trigger of the sound (voice) warning on the glideslope excessive deviation. The PIC affirmed that he had heard this warning by the sentence: *«Informative»*. Compliant to the Aeroflot, PJSC OM (Part B, Chapter 2 Standard Operating Procedures, page 2.3.24), at the flight below DH the activation of the GLIDESLOPE warning is informative and does not require initiating go-around. At that the OM integrates the instruction to monitor the AOA of ≈6°. By continuing the approach, the crew had not departed from the OM provisions.

Note: *In the aircraft designer documentation there is no instruction on the AOA monitoring at the ILS approach. The airline representatives stated that this provision had been introduced to OM out of the FCOM Section 1.04.75 (page 9) that outlines the NPA procedure. Effectively this FCOM Section suggests that the PNF should monitor the 6° AOA into the glideslope descent until MDA/H is reached. At the NPA the AOA shall be monitored to ensure the descent with the established glide path angle at the target speed. When the considerable glide path and/or airspeed deviations are allowed the AOA is changing, which is to signal the departure off the required flight parameters to the crew. The introduction of this condition to the OM as for the ILS approach (when at any moment the crew is able to directly observe the deviation off the target glideslope), even more so for the stage of flight below DH and the events of the glideslope warning activation, makes no physical sense.*

In this part the OM provisions are not in line with the FCOM provisions (Part 1, Chapter 1.04 Standard Operating Procedures, Section 1.04.72 ILS Approach, page 5), which instruct to go around at the activation of any Warning and Caution (except for the engine failure warning) at the altitude between 1000 ft. and 100 ft. By contrast, according to QRH (Emergency and Abnormal procedures, Navigation, A-12, 5-34, pages 19 – 20, TAWS Warnings), at the GLIDESLOPE warning activation it is required to establish the aircraft on glideslope, there are no instructions to initiate go-around in QRH.

Similarly the FCOM Section in question integrates the warning against the ducking under the glideslope and on the necessity to maintain the stabilized angle of descent up to the point of flare. In reality at the final descent there occurred the ducking under glideslope. The analysis of the record of the sidestick inputs in pitch at the segment of the GLIDESLOPE warning activation had been the evidence that it had been a forward (to nose-down) sidestick input for about 0.4°. Bearing in mind that the sidestick trim position into the glideslope flight was 2°– 3° to nose-up, the investigation team observes that it were the PIC's control inputs to have resulted in the increase of the vertical rate of descent and ducking under the glideslope. The PIC confirms it as well at his interview evidence: *«After passing the DH I descended slightly below glideslope to ensure a smoother approach to the runway and maintain the recommended speed[160] before landing of not more than 360 FPM»*.

The investigation team indicates that the value of the vertical speed of 360 ft./min (1.8 m/s), set out in the QRH OVERWEIGHT LANDING Section as maximum allowable prior to touchdown, is substantially higher against the normal vertical touchdown speed (150 – 200 ft./min or 0.76 – 1 m/s), at which the FCOM recommends to perform landing (Section 1.04.80, page 1). In other words at the maintained stabilized approach parameters no specific actions by the crew are required to establish the touchdown vertical speed.

Note: *1. As communicated by the aircraft designer the limitation of the vertical touchdown sink rate at the overweight landing is determined compliant to the AR-25 requirements as to the maximum loads, born by the LG and the airframe structure at this type of landing. The 360 FPM value had been set up at the certification activities and is as well based on the CS-25.473(a)(3) requirement to the vertical speed at the MTOW landing. The 360 FPM value of maximum sink rate prior to touchdown is stated in the QRH OVERWEIGHT LANDING procedure to inform about the limit vertical speed value at landing. This value has a substantial margin against this, recommended by FCOM for the vertical touchdown speed at normal landing (150-200 FPM).*

The vertical speed 150-200 FPM value is given in FCOM as this, recommended by FLIGHT SAFETY FOUNDATION for the transport aircraft (Flight Safety

[160] This stands for the sink rate.

digest – Stabilized approach and flare are keys to avoiding hard landings, August 2004), as the exceedance of the vertical speed by 4 FPS (240 FPM) can already be considered as the hard landing: «Service experience indicates that most flight crews report a hard landing when the sink rate exceeds approximately four per second».

In FCOM the recommended values of the vertical speed are presented as the optimal rage of the vertical touchdown speeds at the landing in compliance to the procedure, stated in Section 1.04.80 page 1. The current vertical speed value is always indicated at the PFD and the potential capture by the crew of this value at the point of touchdown may act as the supporting information at decision-making on the hard landing evaluation and the introduction of the value in the logbook.

Nevertheless starting from the altitude of 100 ft. (30 m) the F/O called out the current vertical speed values eight times. These reports by the F/O had been overlapped with the auto callouts on the flight altitude (through each 10 ft. (3 m), which, against rather intense F/O's voice, established the considerable sound background in the cockpit.

Note: *As per the SOP (Section 1.18.7 of the Report), the current vertical speed is to be called out once at the altitude of 50 ft. AGL. The FCOM does not incorporate this kind of procedure. As explained by the investigation team member to the airline, this procedure had been introduced by the special Instruction in preventing hard landings.*

The aircraft designer documentation incorporates the instruction on the sink rate monitoring at the ILS approach in the FCOM Section 1.04.72 (page 5). At the final approach the PNF is instructed to call out «SINK RATE», if the sink rate exceeds 1000 ft./min.

Fig. 170 presents the flight parameters starting from the altitude of 100 ft. (30 m).

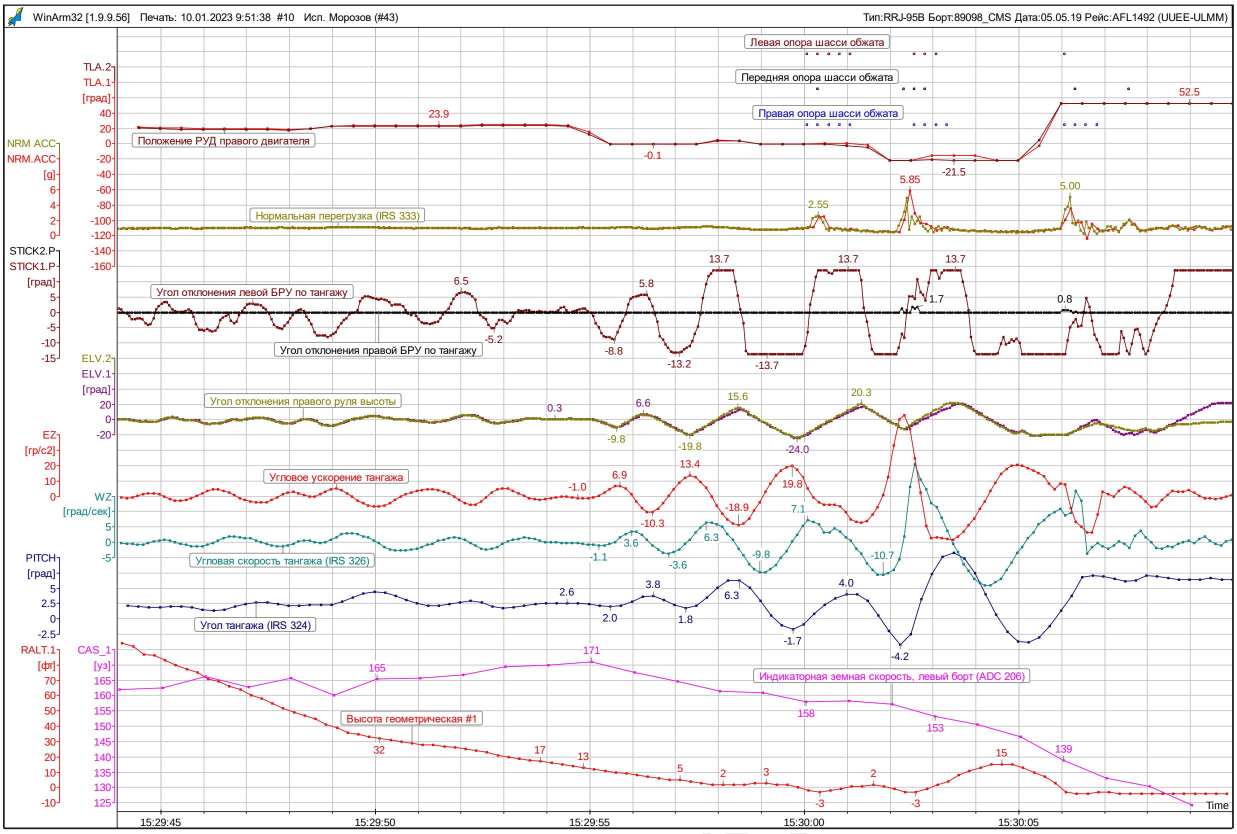


Fig. 170. The flight parameters from the altitude of 100 ft. (30 m)

At the GLIDESLOPE warning activation the PIC increased the engines power rating, but did not take effective actions to recover the descent path (to establish on the target glideslope). This resulted in the aircraft IAS increase: by the point of being flown over the RWY threshold – up to 165 kt (306 km/h), and by the altitude of 16 ft. (5 m) – it did up to 173 kt (320 km/h). The target approach speed (Vapp) was equal to 155 kt (287 km/h). The airline OM sets out the maximum value + 20 kt (37 km/h), being the stabilized approach criterion (see Section 1.18.7 of the Report). This value is inconsistent with the aircraft FCOM, which determines the value + 10 kt (18.5 km/h).

Note: *FCOM Section 1.04.72 page 2:*

THE STABILIZED APPROACH CRITERIA

The approach shall be stabilized by the altitude of 1000 ft. AGL at the IMC approach, or by the altitude of 500 ft. AGL at the VMC approach.

The approach is considered stabilized under the following conditions:

– the aircraft is flown on the target path vertically and horizontally;

– the aircraft is configured for landing;

– the engine thrust is constant, normally higher against the IDLE mode and the aircraft trim ensures the flight at the V_{APP} speed;

– the flight parameters do not exceed the established limitations. See FCOM Section 1.04.72 ILS APPROACH[161].

After the activation of the RETARD auto callout at the altitude of 17 ft. (5.2 m) the PIC proceeded to the aircraft flare: it was a dynamic aft sidestick input up to 8.8° (beyond a half travel) (Fig. 170). The TL were concurrently retarded to IDLE.

The amount of the sidestick actual deflection in pitch was in the range of deflection, occurred in the previous flights, carried out by the PIC at flare. At that the aircraft response in the nose-up direction may have seemed excessive to the PIC, and he rapidly[162] deflected the sidestick back beyond neutral by the amount up to 5.8° with keeping it deflected. It is worth noting that by the point of the PIC's response (the initiation of the sidestick input to nose-down) the aircraft pitch and AOA had not yet had time to noticeably increase, the vertical speed of descent remained virtually constant, and the pitch rate had just started to increase. This way, it is only the pitch angular rate, having seemed excessive to the PIC that he may have responded to. That is to say the response had been the reflex one, that by the senses, with no control of the actual parameters of the aircraft flight.

The investigation team indicates several factors at once that had affected the aircraft motion dynamics in pitch channel and triggered the PIC's sensation of its «excessiveness».

The actual airspeed, having exceeded the reference approach speed by more than 15 kt (28 km/h), was the first factor. The effect of airspeed on the dynamics of the aircraft pitch motion is addressed in Section 1.16.22.10 of the Report. It is clear that with the increase of airspeed the aircraft response in the FBWCS DIRECT MODE becomes more dynamic. At the FBWCS NORMAL MODE the aircraft response is largely independent of the airspeed.

In a way, the investigation team is of the view that the extension of the stabilized approach range by the IAS parameter (up to 20 kt (37 km/h), undertaken by the airline, had been unsubstantiated, irrespective to the potential effect on the aircraft motion dynamics at the FBWCS operation in DIRECT MODE. According to the aircraft designer, neither the airline (at designing the OM), nor the aviation authorities (when coordinating the OM), as far as the values, indicated in FCOM are concerned, had not requested about the potential risks at the range extension.

As outlined in Section 1.16.22.7, at the stage of flare the headwind microburst had as well affected the aircraft motion dynamics that had resulted in an instantaneous increase in IAS. The analysis of the simulation results is the evidence that even with the sidestick actual deflections preserved no microburst results in another (at 3 sec. before the «first» touchdown, recorded by FDR) runway touchdown. The runway touchdown and its perception by the PF might have significantly

[161] See Section 1.18.8 of the Report.
[162] Hereinafter up to the point of the third touchdown, the sidestick deflection rate had been roughly the same and, most probably, consistent with the maximum available (possible) one to this very PIC.

altered the nature of the further control inputs. In such a way, another factor that may have affected the flight outcome, had been the ignorance of the predictive windshear warning by the crew. Following this warning instructions would have resulted in the rejection of approach and the performance of go-around from the altitude of about 1000 ft. (305 m) AGL.

The third factor that may have impacted the «excessive» aircraft dynamics, had been the failure to maintain the established glideslope angle prior to initiation of flare (the ducking under glideslope) and, consequently, the lower original value of the flight path angle and vertical speed of descent. The runway threshold was flown over at the altitude of ~35 - 30 ft. (~ 10 m), which is significantly less of the 50 ft. (15 m) value, which is applied at the calculation of the aircraft landing performance. The recorded flight path angle was about 2° to nose-down and continued to decrease (in absolute value)[163]. With these original «parameters» the sidestick deflection, required for flare, is to be less. The Flight Crew Bulletin on the landing performance technique (FCOM, Section 1.09.11 page 6) determines to this case: *«If … there is a deviation in the descent path before flare, perform go-around».* The crew had not performed go-around and had not considered it, the provisions of the Bulletin had been neglected.

Note: *The Flight Crew Bulletins are an integral part of the FCOM. They are designed in order to provide the flight crew with the technical and/or operational information to supplement the information, actually set out in the FCOM Sections.*

The Flight Crew Bulletins are issued recurrently to address one or several subjects and provide the flight crew with the additional explanations as to the operational procedures, systems description, and flight performance.

The analysis of the PIC's simulator training scenarios indicated that the training program had not provided for the exercises, through which he could have perceived the aircraft response to the sidestick input in pitch in the environment, similar to this of the flight that ended up with the accident. With that it is important to understand that the monitoring of the subject risks is carried out by the timely decision-making and the performance of go-around. The simulation revealed (see Section 1.16.22.9 of the Report), that even at that stage, should the PIC have held the sidestick in the attained position to nose-up (8.8 °) without having increasing the engines power rating, then the aircraft without touching the runway would have transitioned to climb. At the altitude of 20 m the airspeed would have remained close to the approach speed, recommended by FCOM (155 kt), the airplane would have proceeded positive climb with the rate of climb up to 8 m/s, which would have allowed the pilot to calmly increase the engines power rating and complete the go-around maneuver.

[163] The established glideslope angle is ~ 3° (Fig. 29).

The investigation team also points out that all three hazards in question, the combination of which would have resulted in the «excessive» - as perceived by the PIC – aircraft response in pitch, are not directly related to the FBWCS operational mode. By contrast, at the FBWCS operation in NORMAL MODE the adverse manifestation (effect) of the indicated factors would have been «smoothed», the aircraft response would have been less dynamic (see Section 1.16.22.8 of the Report).

Instead of initiating go-around the PIC exerted an abrupt forward sidestick input up to 5.8° to nose-down. The simulation was the evidence (see Section 1.16.22.9 of the Report) that should the PIC have returned the sidestick to neutral (i.e. just had released the sidestick pressure), then the aircraft would have landed on the MLG legs with the vertical acceleration of slightly more than 2.0G without another bounces, and, most probably, the landing process would have been completed safely.

The forward sidestick input beyond neutral had been inconsistent with the conventional flare performance technique. The operational documentation by the most designers to the modern transport aircraft integrates the explicit prohibition on the control handle (the sidestick, the control column) forward input in pitch beyond neutral after the initiation of flare. The issue under consideration is attributed as the general piloting skill and is not anyhow linked with the aircraft type.

Against these prohibitions present, the occurrences of the sidestick deflection to even full forward position at extremely low altitude (in the immediate vicinity of the ground) are recurrent[164], that is to say, the operational documentation set-out provisions only are clearly not enough to eliminate the sidestick forward input at low altitude. The investigation team is of the opinion that there are at least two factors that contribute to the erroneous control inputs of the kind.

The first factor is associated with the apparent deficiencies in the piloting technique at the flare and landing (for the lack of the sustainable skills) that should be identified and rectified by the instructor personnel in the progress of the type transition training, at the commissioning and at the arrangement of the scheduled drills and checks. As appears from Sections 1.16.19 and 2.2.1 of the Report, this weakness in the PIC's piloting technique had not been promptly identified and rectified.

Note: *Likewise the investigation team identified the specific feature in the PIC's piloting at landing that could have further affected the sidestick forward input beyond neutral. As per the materials, presented in Section 1.16.19 of the Report,*

[164] On January 10, 2010 at the Antalya airport (Turkey) the air accident occurred to the A321 VQ-BRS aircraft, the circumstances of which are similar to the event under discussion as regards to the full forward sidestick input at flare. https://mak-iac.org/upload/iblock/155/zuhp3s3lbx2rsut0lts2aqkukqmz8kr5/report_vq-brs.pdf. Section 1.18 of the mentioned Final Report incorporates the additional information on the subject matter.

it follows that at the performance of the most landings at the stage of flare after the initial increase of the pitch attitude to nose-up the sidestick had been deflecting over a broad range. What is more, in a number of flights the sidestick had been dynamically deflected and the pitch attitude had not been held (more often it had been changing to nose-down). Along with that into the landing roll the sidestick had been always deflected full forward (against the stop). As far as such piloting technique is concerned, there is an increased risk of the «too smooth landing» (when the landing roll is proceeded without the occurrence of the WOW signal to the MLG legs and the air/ground transition of the aircraft systems operational logic), the «three points» touchdown or even with the NLG coming first due to the delayed touchdown, for instance, under the effect of the headwind gust immediately prior to touchdown or due to the erratic evaluation of the actual height of the flight.

In the present instance the high psychoemotional tension of the PIC could have contributed to the manifestation of this factor. As noted in Section 1.16.21 of the Report, when having been subject to the psychological testing the PIC demonstrated the mean scores, associated with the precision of the dynamic eye estimation, as well as with the logical and analytical thinking. The dynamic eye estimation (the perception of distance, time, speed and the direction of movement) is determined as the capability to estimate the change of distances to moving objects or between them over time, it is to be applied at the selection of distances and intervals, especially at the complicated maneuvering. According to the expert psychologist, the set of mean indicators of the logical and analytical thinking and these of the dynamic eye estimation, in the general stress condition notably, may induce the significant difficulties and delays not only in the situation evaluation, but in the decision-making speed and accuracy.

The second factor, according to the investigation team, rests in the lack of the basic theoretical knowledge at the flight personnel and the understanding of the aircraft response to the elevator deflection as regards to the ongoing dynamic processes. The risk, deriving of this factor, is associated with the lack of awareness that at the low altitude after the forward control handle input (for instance to impede the aircraft «droop» over the RWY) and the generation or increase of the vertical speed of descent the pilot may just not have enough time to arrest the descent, as the aircraft touchdown may occur earlier. With that at higher altitude the stated maneuver is not anyhow hazardous, that is to say the pilot does not fear it. This factor effect is addressed in more details in the handbook «To the pilot on the prevention of hard landings» (Moscow, the Transport Publishing House, 1990)[165].

The investigation team indicates that the manifestation of this factor (the control handle forward input at the low altitude, notably) is triggered both by the piloting errors into flare and the consecutive separation of the aircraft off the RWY (bouncing), when the pilot wants to settle the airplane on to the runway. At both scenarios forward input beyond neutral of the flight control is unacceptable and the safe way to remedy the situation is to initiate go-around. The PF should be inherently focused on the initiation of go-around (to be «go-around minded»), if the airplane occurred to «droop» over the RWY. The go-around may be performed at any time either at flare or after touchdown, unless the TR is actuated.

The RRJ-95 FCOM (see Section 1.18.27 of the Report) reads the prohibition of the forward sidestick input beyond neutral as well. Indeed the wordings, applied through this FCOM Section, contribute to the ambiguous interpretation of its content at some pilots, to which the airline representatives indicated in the investigation process. By contrast, the airline, having been reasonably hesitant for a long time of the understanding of this FCOM Section, had not addressed any requests to the aircraft designer.

Note: *Similar deficiencies in the documentation drafting had been stated by the investigation teams earlier as well, at the investigation of the other air occurrences (see, for instance, the Final Report on the results of the investigation of the air accident to the RRJ-95B RA-89011 aircraft, occurred on October 10, 2018 at Yakutsk aerodrome https://mak-iac.org/upload/iblock/087/report_ra-89011.pdf). This investigation resulted in the issuance of the following safety recommendations to the aircraft designer:*

- *Arrange the one-time check of the operational documentation for consistency of the limitations, stated in AFM, with the limitations and provisions, integrated in the other documents (FCOM, FCTM, etc.);*
- *Arrange the one-time check (the proofreading) of FCOM, FCTM and other documents to eliminate errors and inaccuracies.*

The magnitude of the sidestick input to nose-down in the flight that ended up with the accident exceeded the values that had been recorded in the PIC's previous flights (at the FBWCS NORMAL MODE). Along with that the accomplished nose-up moment had been even larger due to the initial aircraft trim with the residual forces to nose-up, that is the effective sidestick forward input was by 2° - 3° more. Evidently the aircraft response had significantly exceeded the pilot's

[165] It is published, for example, at: https://favt.ru/public/materials/0up/0a49a395078d46289fae4726c9fd9865.pdf.

expectations and the sidestick after its retainment in the forward position was the fastest possible deflected back to the stop with the retainment as well. As appears from Fig. 170, as before, the sidestick input to nose-up was a distinctly reflex one and was induced at the development of the significant angular acceleration to nose-down, at that the pitch angular rate was still positive and the pitch attitude continued to increase, reaching the value of about 4° to nose-up, which was somewhat less of the normal landing value (5° - 6°). That is to say the further pitch control input to nose-up was not required, one should have just captured the current value of the parameters. Presumably, the PIC did not realize all this, having become psychologically incapacitated, as the current environment was beyond his psychoemotional potential, although did not cause the psychological stupor at him.

It is notably with the psychological incapacitation the fact may be associated that at the post-accident interview the PIC described his sensations at the landing in a way that was inconsistent with the actual circumstances. According to the PIC: *«… retarded to idle. [I] set the landing configuration and further on was waiting for the touchdown»*, that is obviously not in line with the dynamic sidestick repositioning, stated here above.

After the air accident the PIC complained about the «slowness» of the flight control. The airplane, in the PIC's opinion «tracked the sidestick» not fast enough. As the simulation revealed (see Section 1.16.22.5 of the Report), the airplane dynamics into the flight that ended up with the accident had been fully aligned with the type aircraft (engineering model) dynamics. The similar conclusion had been made in relation to the engineering model, integrated in the simulator (see Section 1.16.16 of the Report). The additional comparative simulation indicated that in a number of modes the aircraft response lag in DIRECT MODE against NORMAL MODE is either about the same, or less (see Section 1.16.22.2 of the Report).

At the actual speeds and the amplitudes of the sidestick inputs into the flight that ended up with the accident the aircraft feedback was fully determined by the available rate of the elevator actuators travel. Fig. 171 presents the comparison of the elevator surfaces deflection rates at the full travel sidestick inputs at the check of the elevators to the RRJ-95 and A320 aircraft and into the emergency process in flight that ended up with the accident. By the comparison it is clear that:

- the elevator travel rate at RA-89098 into the emergency is similar to the travel rate at the preflight checks and is determined by the actuator performance;
- the elevator travel rates at the preflight checks at RA-89098 and RA-89011 are the same and in line with the declared values (~ 30 °/sec);
- the elevator travel rates at the preflight checks at the RRJ-95 and A320 aircraft are virtually the same;

- the sidestick input rate at RA-89098 into the emergency had been higher against this at the preflight checks.

This way, the sensation of lag in the aircraft response to the sidestick input had been only attributable to the PIC’s psychological condition and is of the same nature as the reflex control by the perceived accelerations.

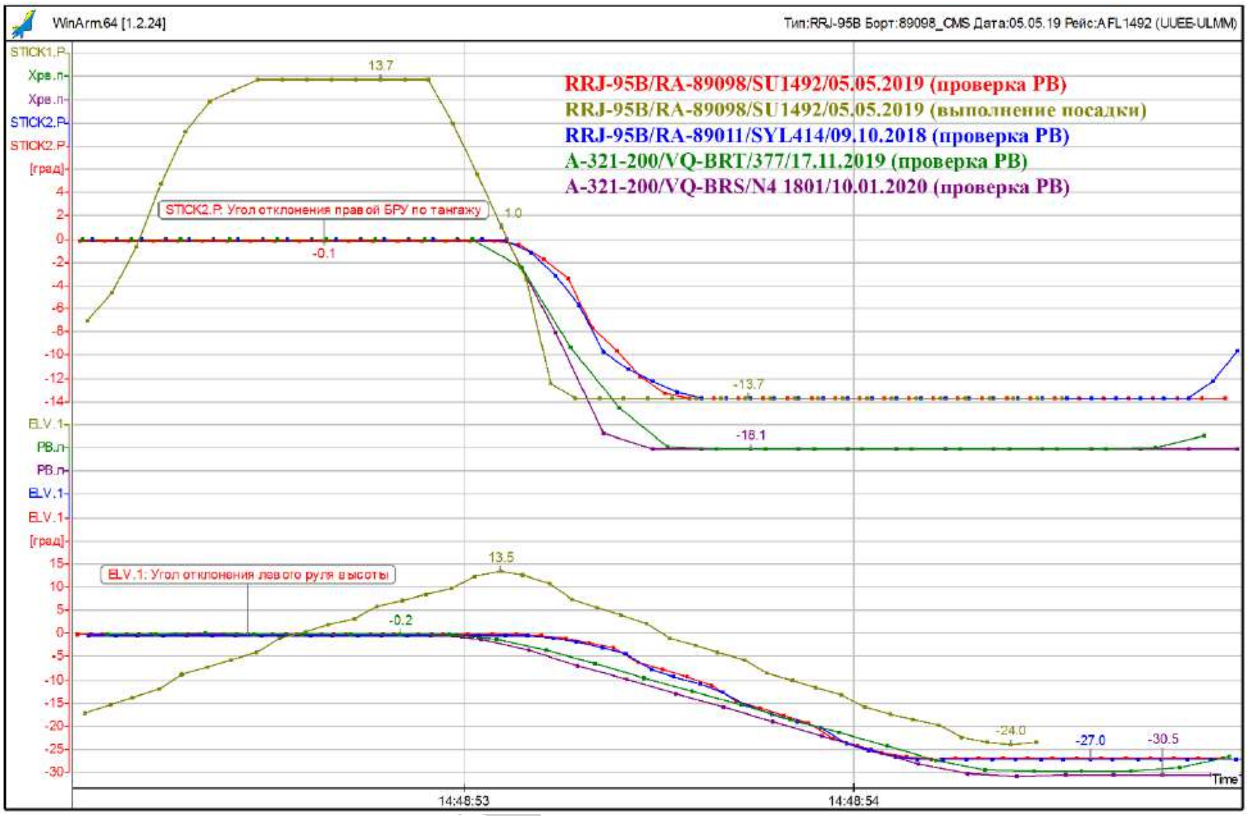


Fig. 171. The comparison of the elevator travel rates at the dynamic sidestick inputs (the time is relative on the Figure)

Further on the alternating sidestick inputs «from stop to stop» with keeping the sidestick retained were continued (Fig. 170), which resulted in the aircraft pitch oscillations in close proximity to ground (the runway). The oscillations in question are the occurrence that may be described as the unfavorable aircraft-pilot coupling/APC. These occurrences are quite rare, unexpected to the pilots, and bring about the hazardous alterations of the aircraft attitude and flight path. If these alterations are oscillatory by nature, then they speak of the PIO (pilot-induced/involved oscillations), i.e. of the oscillatory nature of the aircraft motion, associated with the pilot’s actions. It should be understood that the involvement of the pilot in these oscillations is a mandatory condition, it is the active pilot’s control inputs that make up an airplane-pilot closed-loop system, susceptible to the oscillations. With that this is precisely about the unfavorable (inadvertent) oscillations of the airplane-pilot closed-loop system, but not about the pilot’s deliberate inputs to establish a certain oscillatory nature of the change in any parameter (the pitch attitude, for instance).

They commonly identify three PIO categories (kinds) (see, for example, the results of the research «Aviation Safety and Pilot Control: Understanding and Preventing Unfavorable Pilot-Vehicle Interactions», performed by the National Academy of Science, USA).

The oscillations of the first category are not usually dangerous and are induced, for instance, at the pilot getting used to a new aircraft type (with a different dynamics). The typical of the oscillations of the kind is their «linear» nature, when the flight control surfaces and their travel rates do not reach the structural stops and limits. If the pilot «exits» the control loop, then the oscillations stop.

The oscillations of the second and third category occur at the abrupt change of the aircraft-pilot closed loop system efficient dynamic performance, associated, for instance, with the high-amplitude control inputs by the pilot, the switching of the FCS modes or its failures. With that the oscillations of the second category entail the «nonlinear» occurrences, when the flight control surfaces and/or their travel rates reach the structural stops and limits. The oscillations of the third category entail the cases when the «nonlinearities» are more complex by nature.

Typically the oscillations of the second and third category arise unexpectedly at the crossing of the threshold value by any parameter. For this reason to the oscillations of the second and third category the cliff-like term is applied (as from the word «cliff» – a high area of rock with a very steep side, often on a coast). At the onset of the oscillations of the second and third category, usually, the pilot is unable just (without the emergence of threat to the safety of the flight) exit the control loop to stop them, he appears as if locked up in the control loop, to this his control inputs often aggravate the situation. This assertion is even truer as to the flight close to the ground, when there is a danger of the inadvertent touchdown.

Generally the oscillations of the second and third category occur at the performance of a rather complex piloting task (the performance of landing, for instance) and through exposure to «a trigger» that results in the increasing sophistication of the task and the necessity of the precise piloting with large gains. Both external factors (such as turbulence or strong wind gusts) and the alterations of the aircraft-pilot system «efficient» dynamics: due, for example, to the switching of the FCS operational modes, ***or the alteration of the «pilot transfer function» (including due to the change in his psychoemotional state), as well as the inconsistency between the pilot's expectations (his projected flight image) and actual aircraft behavior*** can appear a trigger. The combination of the stated factors is often encountered.

One should be aware that the onset of the PIO as per the above-mentioned scenario can occur to pretty much any type of aircraft. Indeed the aircraft, integrating modern fly-by-wire control systems are naturally more susceptible to this phenomenon, as they do not have a direct connection between the control handle deflections (such as the sidestick) and the flight control (the elevator, for instance) that may further contribute to the onset of the PIO due to the intrinsically present «lags» of the aircraft response to the pilot's control inputs (the repositioning of the control handle that may be carried out the fastest way possible). These are particularly hazardous situations when the general lag of the system is concurrently increasing (due to the deflected flight control surfaces reaching the structural stops and/or at reaching of the design limits by the actuators in the flight control surfaces travel rate) and the pilots exerts control with the large gains.

The investigation team assumes that it is this type of situation that occurred in the flight that ended up with the accident. While solving a relatively complex task of the piloting (the performance of landing in a precision landing zone against the significantly increased airspeed and allocation below glideslope) the PIC aggressively deflected the sidestick to the limit angles and actually entered the aircraft in the PIO of the first type and after the reaching of the elevator actuators travel rate limits did in the PIO of the second type as well.

At the point of the RRJ-95 certification in the global practice there had been no distinct instrumental indicators to determine the aircraft susceptibility to PIO. It had been a qualitative evaluation by the test pilots. The analysis of the available materials, submitted both before and after the air accident as well as the experiments, held on the simulator, indicate that in terms of PIO the RRJ-95 airplane is acceptable, including the FBWCS operation in DIRECT MODE, and does not trigger their onset at the appropriate sidestick control inputs. Along with that, it is hardly possible to completely «protect» against this effect in terms of design, for example, by limiting the speed and / or the magnitude of the sidestick travel, as the pilot in certain situations must be able to fully accomplish the available deflection rates and do it the fastest possible. Thereby the actual PIO onset into the flight that ended up with the accident, most probably, had been primarily derived from the ***«pilot transfer function alteration» due to his non-optimal psychoemotional condition.***

The aircraft touchdown occurred not earlier than at 15:29:59.966 and not later than at 15:30:00.061 (there is no way to determine the time more precisely against the sampling rate of the data record by the FDR). Over the subject time interval the sidestick was repositioned from ~ 13.1° to nose-up up to ~ 7.6° to nose-up, and at 15:30:00.327 at the latest the sidestick was repositioned full forward (to nose-down). The point of the full forward sidestick input roughly coincided with the point of the accomplishment of the vertical acceleration maximum magnitude, at that the aircraft separation off the runway occurred at 15:31:00.0606 at the earliest. Over the time interval of 15:29:59.966 - 15:31:00.061 the pitch angular acceleration changed from 12.3 °/sec^2 to nose-up up to 14 °/sec^2 to nose-down, the pitch rate – from 5.5 °/sec to nose-up up to 0.8 °/sec to nose-up, the pitch attitude was changed from 1° to nose-down up to 4° to nose-up.

Further on there occurred the aircraft separation off the runway (the bounce). After the bounce off the runway the aircraft vertical shift magnitude of the center of mass did not exceed 5 ft. (see Section 1.18.28 of the Report). Along with that at the intensive pitch rotation of the aircraft the visual evaluation of the altitude by the pilot with the required accuracy as to the piloting might have been considerably complicated or even impossible.

The pilot's actions, recommended by FCOM at the consecutive separation off the runway (the bounce) are stated in Section 1.18.27 of the Report. The investigation team points out that these actions can be effective only in the particular case when, at the point of touchdown, the pitch attitude does not feature a considerable tendency to alter (the pitch rate and the pitch acceleration are close to zero), and the sidestick deflection is close to the «assigned» for the actual landing conditions. It is in this case only «*the pitch attitude alteration»* may be prevented by retaining the sidestick position at the point of touchdown. In a number of cases (for example at the sidestick position at the point of touchdown, being significantly different from the «assigned» one or if the aircraft is in a considerable out-of-trim condition in pitch), the retaining (holding) of the sidestick in pitch can lead to further adverse consequences. In fact these recommendations are efficient only to the case, when the airplane attitude (in pitch) is stabilized at touchdown and is roughly consistent with the landing one.

The investigation team states as well that the landing itself is a process, albeit a short-time one and comprises technically the runway touchdown, the wheels spinning and the WOW to pneumatic tires, the shock absorber impact travel and the recovery stroke. This process may be completed either with the start of the landing roll, or with the aircraft bounce off the runway, while the pilot may not always anticipate this or that course of events. Along with that the pilot grasps the «touchdown point» by the change of the complex of sensations, which may occur at any point of the described process and is interrelated with the perception features, psychoemotional condition and flying experience to every specific pilot. In the event under discussion into the landing the sidestick completed a full travel «from stop to stop», in other words its position at the point of the pilot, becoming aware of the fact of touchdown and subsequent bounce off the runway, broadly speaking, may have been whatever.

At that the investigation team states that into the flight that ended up with the accident the PIC's uncoordinated control inputs had given rise to the divergent pitch oscillations in close proximity to the runway. In consequence both the first touchdown and the subsequent touchdowns had not been derived from the purposeful control inputs by the PIC to flare and land the aircraft or settle it on to the runway at the bounce. The points of touchdowns, as well as the pitch attitude (the aircraft attitude) at touchdown and its dynamics were the random variables.

Note: *As Fig. 170 indicates, there had been no sidestick control inputs by the F/O. The minor impulse deflections of the right sidestick, recorded at the points of the accomplishment of the maximum vertical acceleration at the second and third touchdown (1.7° to nose-down and 0.8° to nose-down at the third one at most), can be explained by the F/O, having held on to the sidestick «smoothly». These deflections had no effect on the handling of the aircraft. At the first touchdown no inputs by the right sidestick are recorded. Given the considerable vertical acceleration, accomplished at the first touchdown as well, the F/O had been more likely never held on to the sidestick at that point of time.*

Therefore after the first touchdown and the aircraft bounce off the runway the only way out of the accomplished situation that could have ensured the safe proceeding of the flight with no excess risks would have been to initiate go-around. The PF should have set the TL to NTO and, without allowing the aircraft reach the stall AOA, selected and retained such a sidestick deflection to nose-up that would have allowed maintaining the pitch attitude, ensuring the positive climb gradient without reaching the stall AOA.

The actual PIC's actions after the first bounce off the runway on the TL setting to the MAX REV position indicate that at this stage he had not considered go-around. Concurrently the PIC went on with the alternating sidestick inputs from stop to stop with keeping it retained, which resulted in another hard touchdown with the destruction of the MLG legs attachment A «weak links» (see Section 2.3.3 of the Report).

It is also worth pointing out that the crew had not followed the provision of the QRH F/CTL DIRECT MODE Section (see Section 1.18.4 of the Report) on the manual speedbrakes deployment after touchdown. The simulation was the evidence (see Section 1.16.22.6 of the Report) that the timely deployment of speedbrakes, most probably, would have allowed preventing the catastrophic consequences even at the maintenance of the actual sidestick control inputs.

The deployment of speedbrakes after the aircraft contacts the runway results in the almost instantaneous and effective decrease in the wing lift and the «pushing» of the aircraft onto the runway[166]. It is the decrease in the wing lift that is considered most important at the subject stage (and not the increase in drag of the aircraft) for the more effective braking. For this reason the deployment of the speedbrakes shall be exerted right after the contact with the runway, as it comes at their automatic deployment at the FBWCS NORMAL MODE. The analysis of the previous occurrences of the landing performance in DIRECT MODE reveals (see Section 1.16.19 of the

[166] See, for instance, Section 1.18.19 and Fig. 125 of the Report.

Report) that in most cases this step had been carried out delayed by the crews, well into the established landing roll and after the actuation of the TR. That is to say, most possibly, at the training of the pilots the importance of the timely (at the point of landing) speedbrakes deployment had not been presented as appropriate. It is interesting to note as well that in two cases, to which, similarly to the flight that ended up with the accident, the two-time bounce off the runway had been observed, it is with the speedbrakes deployment that the further bounces had been arrested by the crews.

Note: *It should be pointed out that in a number of the QRH and FCOM Sections to designate the aircraft contact with the runway two different terms are applied: «touchdown» and «landing». There are no definitions of the stated terms with the indication of their potential different interpretations. As to the operational documentation provisions under consideration the difference in terms may lead to the inaccurate interpretation of the flight stage.*

At the second runway touchdown the crew did not manually deploy the speedbrakes either. The NLG touching down first with the significant vertical speed, as well as the sidestick full back input induced the intensive aircraft rotation to nose-up, the increase of lift (AOA) and the consecutive bounce to the height of about 15 ft. This time, into the bounce, the PIC attempted to go around by setting TL to MAX position, which was consistent with the FCOM provisions for the «high bounce». The engines power rating was not changed as FADEC automatically maintained the idle mode against the TR doors not stowed. At that stage it was not possible to proceed go-around, it had been the aircraft third hard landing.

Note: *Normally at the go-around a pilot sets the TL to the TO/GA detent. To set the TL to the MAX position one should by applying the 20 kg force step the intermediate TO/GA detent. The almost instantaneous setting of the MAX power rating into the flight that ended up with the accident without holding up at the TO/GA detent further supports the PIC's increased psychoemotional condition.*

2.2.6. The analysis of the crew's actions after the onset of fire and at the emergency evacuation

The hard touchdowns and the erupted ground fire resulted in the failure of the number of aircraft systems, as well as in the trigger of several failure warnings, including the spurious ones (see Sections 2.3.3 and 2.3.4 of the Report). The situation developed rather transiently. The analysis of the records out of the flight recorders is the evidence that the crew had not been fully aware of the extent of damage and the current technical condition of the aircraft.

Thus, for instance, the first 10 seconds of the landing roll (down to the speed of ~ 100 kt (185 km/h) had been proceeded at the TL set on the TO/GA detent (the engines themselves at that ran on idle), along with that a number of parameters had been indicated, evidencing the engines TR system failures. Nevertheless at the speed of about ~85 kt (157 km/h) the TL had been reset by the PIC to the MAX REV position, at that there had been no change to the engines power rating[167]. The PIC had applied the braking to the MLG wheels as well, although they had been disintegrated and the «roll» had gone on with the pitch attitude of about 6° to nose-up.

More than likely, the psychoemotional condition of the crewmembers at this stage may be defined as the highest tension or distress, when the flight image is totally disrupted. The tension could have been further aggravated with the failure sound warnings and synthetic voice, triggering in the cockpit. The experience of the air accident investigation reveals that in this condition it is the highly automated actions only that can be accomplished by the crew. As a matter of fact into the landing roll the F/O reported the stowed condition of the ground spoilers and TR, the check of condition of which is the SOP item and is carried out in every flight. Along with that the red warnings trigger, the fire in the rear baggage hold or the APU FIRE[168] inter alia, had not been called out. Into the landing roll the PIC effectively maintained the aircraft on the centerline with the rudder and instinctively applied the differentiated braking. Both actions are highly automated and carried out reflexively, still in the environment under consideration the braking made no real sense. At that the PIC did not respond to the F/O report on the undeployed condition of the ground spoilers, although earlier in the flight the crew had discussed that the ground spoilers should be manually deployed in DIRECT MODE.

In view of the stated as far as this stage is concerned the investigation team only reviews the performance of the emergency evacuation procedure by the crew, as the rest of the required steps either integrate this procedure, or could not have anyhow affected the outcome of the flight and the severity of consequences.

The emergency evacuation procedures as per the QRH and airline OM are given in Section 1.18.9 of the Report. The procedures are virtually identical in their essence, at that in OM the order of actions is specified.

The first item of the procedure instructs to stop the aircraft. In fact the aircraft stopped before the PIC commanded to carry out the emergency evacuation procedure. As evidenced by the PIC he realized that the fire was onboard just at the final landing roll, when the aircraft started to deviate off to the left and he had visually detected the flame.

The aircraft stop occurred at 15:30:38. At the same point of time the CVR recorded the F/O's command to the flight attendants: *«Attention crew! On station. Attention crew! On station».* According to the OM this command is the fourth item of the emergency evacuation procedure and

[167] All the while, FADEC automatically – consistent with the design integrated logic - maintained the idle.
[168] According to the OM the APU FIRE procedure is one of eight emergency memory items.

is to be carried out by the PIC. At that, until the time point under consideration there had been no command by the PIC to even carry out this procedure.

Note: *The issue of the command by the F/O (and not by the PIC) before the start of the emergency procedure performance aligns well with the results of the pilots' psychological profiles examination (see Section 1.16.21 of the Report). As per the psychologist's conclusion, in the stress environment the increase in excitation is typical to the F/O and the retardation is to the PIC.*

Compliant to the OM the command in question is issued via the PACIS. At the interview the F/O confirmed that according to him he had applied the PA button (Fig. 134). However this sentence is not audible on the sound channels to the passengers' cell phones. At that the FDR record is the evidence that over the same time interval the discrete signal is recorded of the external radio contact initiation via VDR2, in other words the F/O instead of the PA button mistakenly applied the INT/RAD switch (Fig. 134), which he had earlier used to conduct the radio communication with ATC.

Note: *These command is not audible on the ATC recorder. It had been more likely not aired due to the destruction by then of the VHF2 antenna, installed in the lower rear fuselage, having been exposed to both intensive mechanical effect and the fire. After the air accident no VHF2 antenna elements had been retrieved.*

At 15:30:40 the F/O uttered the sentence (commanded) *«Evacuation»*. This sentence (command) is not provided for by the SOP, defining the emergency evacuation procedure and described in the OM (see Section 1.18.9 of the Report). By contrast, the sentence (command) is stipulated by the QRH (see Section 1.18.10 of the Report). Inside the passenger cabin (as recorded by the cell phones) this sentence is not audible. As per the available information the ACP configuration cannot be determined. There is no external radio contact discrete signal recorded by the FDR at that point of time. At that the sentence is too short and the associated discrete signal could just not have been captured against the sampling rate (the record is enabled with the 1 Hz rate). Furthermore, as indicated in Section 1.18.25, at that moment, most probably, the EMER mode could have been activated, that is to say this command could have been heard by any of the flight attendants, if they «had engaged» in this mode and proceeded the monitoring. Nevertheless, based on the available information, it is impossible to determine which flight or cabin crewmember had activated the EMER mode and who could «have engaged» in it.

At 15:30:41, the PIC requested that the standard operating procedure for emergency evacuation be carried out. At 15:30:44 the F/O called out starting doing it.

The emergency evacuation procedure is to be carried out by the crew on a READ – DO principle. The procedure is not displayed on EWD, that is why its reading should be proceeded by a special sheet that in flight is allocated easily accessible. This is how the F/O at the interview described the further sequence of events: «*The PIC gives the command right away for the emergency CHECK LIST. I can remember that I poked and it is not here. I move away and the CHECK LIST, it rolled under the seat. I pull it out and start reading* ...». It is the sentence by the F/O, recorded by the CVR at 15:30:48: *«It fell out»*, uttered «anxiously» and as if «from far away» (the record of the open microphone).

The CVR stopped recording at 15:30:53.3. Up to this point of time there had been no reading recorded of the emergency evacuation procedure items. In a second before the record stop there is another F/O's sentence (command) *«Evacuation»*. As in the previous case, the ACP configuration cannot be determined and whether this utterance (command) had been aired to the passenger cabin.

At 15:30:58 the FDR recorded the signs of the parking brake setting ON by the crew. This step is a second item of the emergency evacuation procedure and is to be carried out by the CM in the left seat. After the air accident the parking brake had been observed set ON (Fig. 20).

No attempts are recorded to notify the ATC (the third item of the procedure). This step is to be carried out by the CM in the right seat.

As the CVR stopped recording it has not been possible to determine whether the command *«Attention crew! On station. Attention crew! On station»* (the fourth item of the procedure) had been given once again.

The fifth item of the procedure is the switch of the engine master switches to the OFF position, which should result in the engines shutdown. This item is to be carried out by the pilot in the right seat without the check and acknowledgement by CM2. After the accident the engine master switches had been observed in the OFF position (Fig. 20). Along with that as indicated in Section 2.3.4, their switching to the OFF position had been carried out at 15:31:34 at the earliest.

The sixth item of the procedure is the release (activation) of the ENG FIRE switchlights to both engines and the APU FIRE to the APU. With the release of these switchlights, inter alia, the wing shutoff valves to both engines are closed and the fire extinguishing system is armed. This item is to be done by the CM in the right seat without being checked and acknowledged by the CM2. After the air accident all three switchlights had been observed in the released (activated) position (Fig. 21). The analysis of the available data out of the recorders revealed that, most probably, the release occurred at about 15:30:43 to the left engine, at 15:30:53 to the right engine and at 15:30:57 to the APU. The wing SOV to both engines had not closed, as by the point of the ENG FIRE switchlights activation the respective communication lines had been damaged, having been exposed to the off-design mechanical loads and fire (see Section 2.3.4 of the Report for details). The APU shutdown had occurred earlier.

The seventh item of the procedure is the manual[169] actuation of the engines and APU fire extinguishing system. This item is to be done by the pilot in the right seat without the check and acknowledgement by CM2. At that the system is actuated «as required», that is at the active warnings on the engines and APU fire. The ENG FIRE warnings had not triggered, the APU FIRE warning had activated at 15:30:34, and still there are no reports on its activation. At 15:30:58 the APU Fire Bottle is Empty discrete signal is recorded, but there had been no record of the discrete signal to the bottle discharge. After the air accident the investigation team had the fire extinguishing system bottles subject to weighing. It had been stated that all the inspected bottles are not discharged. The bottle to the APU fire extinguishing system had not been retrieved. Hence, the crew had been more likely not to have actuated[170] the engines fire extinguishing system (potentially there is a variant that the crew had attempted to actuate the fire extinguishing systems, but all the associated signal delivery circuits had been disrupted). Most possible the APU fire extinguishing system had never been actuated either, and the onset (record) of the discrete signal, mentioned here above, had been due to the exposure to fire.

Note: *As clarified by the aircraft designer, either way the fire extinguishers discharge into the left and right engine, as well as into the APU could not anyhow affected the general course of the fire, as the fire suppressant amount to the propulsion powerplant and APU is aimed at the fire isolation and elimination only in the volume of the bays to the engines nacelles and APU respectively.*

The next item of the procedure is the evacuation declaration by the left seat pilot: *«Passenger Evacuation. Passenger Evacuation»*. This announcement is to be made over PACIS loudspeaker. These sentences had been recorded neither by the CVR, nor by the cell phones. It has not been possible to identify whether this command had been given after the CVR stopped recording.

The last step of the procedure is the switching off of all four batteries. This item is to be done by the pilot in the right seat without the check and acknowledgement by CM2. Up to the point of the FDR record stop all the batteries remained in the switched-in condition. The total aircraft power off occurred at 15:31:10 consequently to the activation of the circuit-breakers. After the air accident the position of the respective switches had been consistent with the deactivated condition of the batteries (Fig. 22). It has not been possible to determine by the available data when specifically the crew did these actions.

[169] The aircraft is not equipped with the automatic fire extinguishing system discharges.

[170] It has not been possible to conclude on the actuation of the system by the post-accident position of the associated switches, as it (the position) is not «locked».

Thus, based on the available recorded data the investigation team makes general conclusion that the emergency evacuation procedure, stipulated by QRH and OM, had not been systematically (in a READ-DO mode) carried out by the crew. Certain elements to the procedure had been carried out in «a chaotic way», most probably «by memory». Eventually, the aircraft engines had been shut down with a significant delay, which had adversely affected the fire propagation rate and, most probably, the severity of the air accident outcome. At that, as there is no recorded evidence on the propagation of the fire destructive factors, it has not been possible to quantify this adverse effect.

The only one record of the PIC's brief interrogation[171] has been available to the investigation team, which had been held immediately after the air accident. It contains very little specific information about the sequence of the flight that ended up with the accident in general and landing/landing roll in particular. As far as the subject matter is concerned the PIC only affirms that it had been he at the controls at the landing and landing roll. He had felt just one bounce off the runway. Similarly the PIC communicated that *«after the aircraft stop the evacuation had been announced to the passenger cabin over a PACIS»*.

The following available interrogations and interviews records, as well as the explanatory notes by the crewmembers, date back to the time of May 24-29, when the aircraft recorders data had been already decoded and roughly analyzed. This is how the crewmembers had described at the interrogation their actions over the final stage of the flight.

The PIC: *«After the third touchdown we went on with the landing roll … I did not feel any collapse, actually. [I] actuated TR and applied braking. [I] did not feel much braking after the application of pedals. My thought was that was originally related to the weight and then, when the aircraft started to deviate off the runway centerline, I tried to maintain it, I realized the aircraft was out of control. Then there was a runway veering off and the counterclockwise turnaround. After we entered the turnaround I saw the smoke, the trail behind the aircraft. Smoke with fire. I realized the airplane was on fire. After the complete stop I set a parking brake ON. Right away I commanded the F/O to do «emergency evacuation» CHECK LIST. Having fire in sight I gave the command on the emergency evacuation to the passenger cabin. As it was a fire, [I] decided not to wait for the CHECK LIST items by the F/O, immediately shut the engines down and released the fire shut-off valves».* The follow-up question: *«Did you check the engines shutdown? »*, the response: *«I repositioned the switches to the OFF position and released the fire valves. Further in the CHECK LIST item «the fire extinguishers squibs discharge», pushed «discharge» – the pushbuttons to actuate the fire extinguishment».* The follow-up question: *«Which ones? »*, the

[171] Due to the PIC's health issues upon his request the interrogation had been rescheduled. Over the next several days for «medical» reasons it had not been possible to get the crewmembers' evidence.

response: *«To the engines and APU. And similar to the fire shut-off valves – these to two engines and the APU».*

The F/O: *«We are coming to stop. I instantly feel the jet fuel smell, such a strong one, in the cockpit. It seems to me I even uttered it then: «Smell of fuel»*[172]*. That's it, we are stopping at once. I press the button… [I] say: «Attention crew, on station! Attention crew, on station! ». The PIC promptly commands to do the emergency CHECK LIST. I can remember I poked and it is not here». «I move away and the CHECK LIST, it rolled under the seat. I pull it out and start reading «Park/alternate brake ON», then «Engine FIRE…», that is the fire valves should be released and the master switches set to OFF». «And there I am getting confused. Because I start reading, I look at them and they have been already released and the masters have been already switched to the OFF position. I am as if well, kinda me too I should do something. And the PIC tells me: «That's all, I have already switched off».*

The crewmembers' responses are the clear evidence that by the point the interrogations were held they had the fairly detailed knowledge on the basic flight data change and the CVR content. The explanations are «a mixture» of the description of the actions, stipulated by FCOM in the context of the actually recorded information, trying to explain it. At that it involves a number of controversies as far as the actually recorded data are concerned, when it is «not in line with FCOM», first of all, with the sequence and time of doing certain actions (for example, the engines shutdown and the fire extinguishing system actuation). In view of the stated, the results of the interviews of the crewmembers do not allow to appropriately assess the image of the flight (situational awareness), which they had right into the accident sequence.

2.3. The analysis of the aviation equipment serviceability

2.3.1 The analysis of the consequences of the aircraft exposure to the atmospheric electricity discharge

The analysis of the previous occurrences of the RRJ-95 aircraft type, having encountered lightning in operation (see Section 1.18.2 of the Report) is the evidence that no significant damage had been observed to the aircraft structure at the exposure to lightning, or there had been no damage at all. There had been no considerable effect of the atmospheric and static electricity to the operation of the aircraft systems and equipment through the operational period (except for the occurrence under consideration) recorded either.

In the course of the investigation the results of the certification activities had been reviewed in terms of the actions on the protection of the aircraft systems, equipment and structure from the effect of lightning, static electricity, high intensity radiated fields/HIRF, including the results of

[172] This utterance had been recorded by the CVR.

experimental confirmation of the compliance to the current regulations. The analysis outcome had been the confirmation of the completeness of the performed activities.

The compliance of the RRJ-95 aircraft type design in terms of lightning and static electricity protection with the Certification Basis requirements, as by the results of the certification activities, had been confirmed in the «Summary Report RRJ0000-RP-106-1096 on Establishing Compliance of the RRJ-95B Aircraft Type Design with the Certification Basis Requirements For the Lightning and Static Electricity Protection». Inter alia, the compliance to the applicable 25.581(a), (a*), (2), 25.672(a*) items had been established and confirmed. The summary report had been agreed upon by the accredited certification centers and approved by the IAC Aviation Register.

The requirements to the specified items of the AR-25 Aviation Regulations establish:

«25.581. Lightning protection

(a) The aircraft must be protected ***against the hazardous or catastrophic[173]*** *effects of lightning and static electricity.*

…

(a) Tests and computation to the lightning effect must be carried out on the basis of the conditions of the aircraft exposure to the electric discharges, indicated in the Appendix to this item.*

…

(2) The passing of the lightning current along the aircraft hull must not induce the failures or the spurious trigger of the functional systems and equipment that would result ***in the hazardous or catastrophic[174]*** *failure condition.*

25.672. The flight augmentation systems, automatic systems and boosted control

(a) The fly-by-wire control system that operates by the low-voltage signals, must be protected against the external effects (for example, the radiated fields, static discharges, and lightning strikes).*

…

25.1316. The systems protection against the lightning effect

(a) Every electrical and/or electronic system, the disrupted operation of which could impede the safe continuation of the flight and aircraft landing performance, must be designed and installed in such a way that at and after the aircraft exposure to lightning it operates normally.

[173] It has been highlighted by the investigation team. The definition of the environment according to AR-25 see in Section 1.18.12 of the Report.

[174] It has been highlighted by the investigation team.

(b) Every electrical and/or electronic system, the disrupted operation of which may degrade the aircraft or the flight crew capability to handle the adverse operational conditions, must be designed and installed in such a way that its normal operation is ensured after the aircraft exposure to lightning.

(c) The compliance to the lightning protection criteria, addressed in items (a) and (b) to this para, must be demonstrated for the occurrences of the aircraft encounter the standardized lightning discharge ...».

The stated AR-25 requirements complement each other as the situation, described in item п. 25.1316 (a), matches the Catastrophic Failure Condition estimate, whereas item 25.1316 (b) does to the Emergency.

The CS-25 requirements in the part, being discussed, are more lenient, as they allow the onset of even the emergency at the aircraft encounter lightning:

«CS 25.581 Lightning protection

(a) The aeroplane must be protected against catastrophic lightning effects.

(See CS 25.899 and AMC 25.581.) ».

In summing up the stated items requirements the investigation team comes to the general conclusions as follows:

- the airplane and its systems must be protected by design against the effect of the ***standardized*** lightning or static electricity discharge;
- the regulations allow for the structural damage and/or the systems failures that degrade the flight safety, but their consequences are estimated no worse than «the Major failure condition»[175].

The analysis revealed that as the result of the in-flight aircraft exposure to the atmospheric electricity to both EIUs channels A in the time interval of 15:08:06 – 15:08:24 there occurred the transition (reboot) to a new long-term memory sector with the processor operation interruption for the time of ≈ 18 sec (the time record sampling rate is 6 sec.). This transition could have been induced either by the power off at the units channels A input, or a short-term fault to the units channels A, at that the results of the examination of the EIUs had not allowed to certainly determine the reason for the reboot (see Section 1.16.2 of the Report).

As stated by the EIUs designer, their reboot is one of the operational modes and does not constitute a sign of failure (malfunction). Along with that the event of the EIUs in-flight reboot, including as the outcome of the exposure to lightning, had not been on the list of the scenarios, reviewed in the progress of the type certification, these consequences had not been estimated.

175 See Section 1.18.12 of the Report as well.

Meanwhile, as the reboot process results in the EIUs operation interruption and the delivery of the respective information to the aircraft systems, technically (as far as the aircraft systems are concerned) this mode is a failure, though a short-term one.

As per the Fail-Safety Analysis to the RRJ-95B Aircraft Central Processors RRJ0000-RP-106-1205, the concurrent failure of two EIUs entails the Major failure condition. At that the FBWCS reverts to DIRECT MODE with the associated indication and alert activation. This estimate had been confirmed in the progress of the certification flight tests with the participation of the IAC Aviation Register and EASA experts. The crew actions in this environment are described in FCOM and QRH (see Section 1.18.4 of the Report).

Note: *The event of the concurrent reboot to only EIUs A channels had not been addressed at the certification. The analysis, conducted within the investigation, was the evidence that in terms of fail-safety the occurrence of the simultaneous reboot to the A channels is considered not inferior to the total failure of both units.*

In the flight that ended up with the accident there occurred the A/P disconnection and the FBWCS reversion to DIRECT MODE. Likewise due to the exposure to the atmospheric electricity there had been the failure of VDR1 (see Section 1.16.7 of the Report). The other two VDRs had been serviceable. The in-flight failure of one VDR is attributed as the Major failure condition. The expert assessment of the combination of these two occurrences, given that the FBWCS reversion to DIRECT MODE is expertly attributed as «the major failure condition» only at the NPA and go-around (whereas at the other stages it is classified as the Minor failure condition), indicates that, as far as the flight that ended up with the accident is concerned, the total complexity of the environment into the flight that had ended up with the accident had not gone beyond the Major failure condition category, which implied the ensurance of the AR-25 and CS-25 requirements, mentioned here above.

It is worth noting apart that after the aircraft encountered lightning there had been no power loss on any of the DC or AC buses, as demonstrated by the FDR record.

2.3.2 The analysis of the RRJ-95 RA-89098 aircraft performance compliance to the type aircraft performance and the FFS performance in DIRECT MODE

In course of the interviews and interrogations the PIC testified that to his opinion the flight control system had operated inappropriately after the reversion to DIRECT MODE. Along with that the stability and controllability performance of the aircraft had been substantially different against these at the practicing of DIRECT MODE at the FFS. The analysis of potential reasons for this PIC's opinion in terms of «human factor» is presented in Sections 2.2.4 and 2.2.5 of the

Report. In this Section the «technical» aspects of the matter in question have been subject to analysis.

In the progress of the investigation the investigation team had analyzed the compliance of the RRJ-95B RA-89098 performance into the flight that ended up with the accident to the type aircraft performance. The simulation was the evidence (Sections 1.16.22.3 and 1.16.22.5 of the Report) that, as far as the reviewed modes of flight are concerned, including the stages of flare and touchdown, the RA-89098 aircraft performance had fully complied with the type aircraft performance. The aircraft motion had been totally determined by the FBWCS operational modes, the control handles deflection, the targeted engines power ratings and the actual external disturbances (the wind).

Into the investigation the investigation team analyzed as well the compliance of the FFS, on which the training had been arranged to the flight crewmembers, with the established requirements (Section 1.16.16 of the Report). Based on the results of the performed works the FFS in question had been determined fully compliant to the Qualification Test Guide, QTG provisions both in NORMAL MODE and DIRECT MODE. In the special section of the examination of the FFS compliance to the accident flight parameters it had been found that up to point of touchdown, when the PIC started to operate with the alternating sidestick inputs against the stop positions to nose-up and nose-down with the sidestick retainment, the satisfactory convergence of the behavior of the FFS and the aircraft in the accident flight is observed (as per the QTG criteria). When operating with the full travel alternating sidestick inputs in pitch with the sidestick retainment against the stops, over the particular short intervals (less than a second) the parameters of the pitch motion (the pitch attitude, notably) at the FFS go slightly beyond the range of acceptable tolerances (as per the QTG criteria). Along with that it had been identified that the real aircraft damping in pitch is larger against this to the FFS. In other words the task of «holding» and maintaining the target pitch attitude in DIRECT MODE at the substantial sidestick inputs on the real aircraft is solved easier against the FFS. This conclusion is further supported with the flight evaluation by the test pilots.

2.3.3 The analysis of the structural damage, the causes of the fuel spillage and the compliance to the certification requirements

In the accident sequence there occurred the fuel spillage with the fire eruption.

For the onset of the fire three material factors should be concurrently present, being in interaction:

- the combustible substance;
- the oxidizer;
- the ignition source, capable to induce the reaction between the first two.

The video footage is the evidence that the stated conditions for the fire eruption had been accomplished at the third runway touchdown by the aircraft (see Section 1.16.18 of the Report for details).

By contrast, the applicable airworthiness standards (the AR-25 and the equivalent European regulations) integrate certain requirements to the aircraft design (item 25.721 reads the requirements to the landing gear design, notably), aimed at ensuring that *«the fire onset hazard is not constituted»* (see Section 1.18.22 of the Report for details).

This Section reviews the nature and causes of the wing fuel tanks disintegration that had resulted in the fuel spillage, as well as the compliance of the aircraft design to the airworthiness standards as to the subject area.

As per the flight recorders data at the aircraft landing with the weight, higher than the maximum landing one (the overweight landing), there occurred the porpoising with three consecutive runway touchdowns (landing impacts).

The first touchdown occurred with the vertical acceleration of not less than 2.55G, which exceeds the maximum limit ones (2.25G according to AMM 17-51-00-200-801) and, against the exceedance of the maximum landing weight, is attributed as a «*very hard landing*».

Note: ***AMM Section 17-51-00, work 200-801, page 606***

The aircraft hard landing with the weight, exceeding the maximum landing one, implies the landings with the vertical acceleration of 1.94 – 2.25G, the landings with the acceleration higher than 2.25G are attributed as the very hard ones.

The calculated value of the vertical speed of descent at the point of touchdown amounted to 3.2 m/s. As indicated in Section 1.16.17, at the first touchdown the absorbed energy exceeded the values, calculated compliant to the AR-25 item 25.473 - for the limit loads determination (for the vertical speed at touchdown of 3.05 m/sec), but had not exceeded the values of the ultimate loads determination (for the vertical speed at touchdown of 3.74 m/sec). The analysis of the flight recorders and the other available data revealed no evidence of any structural destruction as the outcome of the first touchdown.

At the second touchdown, the vertical acceleration had been 5.85G at least, the design vertical speed of descent had been 4.2 m/s. The calculated value of the absorbed energy for the actual landing weight was ~ 190 % against the ultimate loads values (for the vertical speed at touchdown of 3.74 m/s). Such a significant amount of absorbed energy, in addition to the increased vertical speed of descent, is linked with the intensive rotation of the aircraft in pitch at the point of touchdown (Fig. 56). The ultimate loads, having been applied on the MLG, had been equal to 1111 kN (113.3 tons). As by the results of the analysis, presented in the Report «Analysis of the implications of the MLG legs destruction or the performance of landing with one or more landing gear legs failed to extend to the occurrence of the fuel spillage out of the fuel system enough to constitute a fire hazard», RRJ0000-RP-100-1324, Rev. A., 2010, the fuse pins/«weak links» to the A attachment[176] are destructed when the vertical load of 981 kN (100 tons) is exceeded (Fig. 130). Thus, the actual loads on the MLG Attachments A to the wing rear spar exceeded the destructive ones, which led to the shearing of the fuse pins («weak links») of the A attachments to both MLG legs. With that, the analysis of the destructed «weak links» stated their conditionality (Section 1.16.13 of the Report).

In addition to the simulation of the magnitude of loads, having been applied on the landing gear, the destruction of the Attachment A «weak links» right at the second touchdown is supported by the analysis of the FDR record. After second touchdown there had been a simultaneous decrease of pressure in hydraulic system 1 and hydraulic system 2, which indicates the disruption of the hydraulic circuits. The inspection of the hydraulic system paths over the Attachments A revealed that they had been damaged by the Attachments A at their upward movement, which is consistent with their anticipated direction of movement at the reviewed way of loading (the vertical impact). At the occurrence of the irreversible event (the accomplishment of the safe destruction feature) at the application of the load, exceeding the ultimate one, with the prevailing vertical component (as in the case under consideration), there occurs the shearing of the Attachment A fuse pins and the upward turnoff of the crossarm FWD part up to the point of the forces redistribution on the side and drag braces.

The separation of the attachment fittings to the left and right MLG legs off the wing rear spar at the second touchdown had not resulted in the disruption of the wing box structure and fuel leakage, which is evidenced by the following:

– the FDR had not recorded the fuel leakage;
– there are no signs of the fuel leakage after the second touchdown as per the CCTV footage;
– there had been no aircraft structural elements and fuel leakage traces retrieved at the zone of the second touchdown.

Along with that the complete separation of the landing gear legs structure had not occurred at the second touchdown. As seen on Fig. 130, the leg with the disintegrated Attachment A continues to bear the load. The next element to disintegrate at the application of the vertical load is the LG crossbeam attachment to the wing, the required destructive load is 124 tons. There had been no loads of this magnitude, applied on the LG structure at the second touchdown. In this way the destruction of the LG structure had been proceeded compliant to the simulation scenario until

[176] Section 1.18.21 of the Report reads the MLG legs design.

the energy, absorbed by the aircraft structure, had been enough to generate the required force on the leg, and it had been stopped at its exhaustion.

As it had been pointed out earlier in the Final Report on the results of the investigation of the air accident to the RRJ-95B RA-89011 aircraft, occurred on October 10, 2018 at Yakutsk aerodrome[177], as of today the stand of the certification authorities at the compliance demonstration to item 25.721 proceeds from the following basic assumptions and limitations:

- only the events are reviewed that occurred on the artificial RWY;
- only a limited number of basic scenarios (design cases) of loading are considered, being attributed as the «worst of the most probable», but which do not cover all potential situations, which, inter alia, may occur due to crew's erroneous actions or the failure to comply to the established limitations as well;
- it is only the first (one-time) exceedance of the destructive load that is addressed. The loads, induced into the subsequent movement of the aircraft, and the damage, caused by them, are not regarded.

The aircraft designer had claimed as well that at designing the landing gear one of the conditions, taken at the simulation of the design cases, is that the destruction (separation) of the MLG leg up to the complete one without causing the fuel spillage in the amount enough to constitute a fire hazard at the one-time application of the load, exceeding the ultimate one, shall be demonstrated.

This fact is supported by the stand of the certification authorities on the interpretation of the separation term (see, for example, CRI EASA, Section 1.18.22 of the Report).

As indicated by the aircraft designer, at the engineering simulation in the progress of the certification activities the situation had been simulated, at which the separation of the LG leg off the airplane occurred at the application of the infinitely increasing load and at the leg unlimited motion, that is as per the assumption on the unlimited added energy. These magnitudes of loads generally exceed these, actually applied on the structure at the air accidents and incidents, that is to say «in the real world» (operation) the complete separation of the landing gear at the first application of the destructive load is highly improbable.

Indeed the simulation had been the evidence (Section 1.16.17 of the Report) along with the other activities, held in the progress of the investigation, the loads, accomplished at the second touchdown, should not have resulted in the destruction of any landing gear attachment elements, but the Attachment A «weak links». Practically, the investigation team had not identified the signs of any other destruction at the second touchdown either.

[177] The Final Report is published by the link: https://mak-iac.org/upload/iblock/087/report_ra-89011.pdf.

Similarly in the Safran Landing Systems/SLS landing gear designer report the data are stated that the minimum safety margin (factor) of the integrity of the landing gear attachment elements, for which SLS is responsible, against the ultimate conditions is ~ 2.45 (that is, the certification ultimate safety margin equal to the safety margin without a one, expressed as a percentage, is 145%). The indicated values refer to the Attachment B trunnion pin, to the other attachments they are even larger. At that, according to the AR-25 items 25.303 and 25.473, the safety margin (factor) can be equal to 1 (that is, the certification ultimate safety margin is 0%).

Note: *The magnitudes of the safety margin or the ultimate safety margin to the MLG attachment elements, which the aircraft designer is responsible for (except for the Attachment A «weak links»), including the landing gear retraction/extension actuating cylinders mounting brackets, had not been submitted to the investigation team. Still the available data allow stating that the safety margins to the attachments in question are as accordingly large.*

As explained by the aircraft designer, the reason for such a significant ultimate safety margin against the minimum values, allowable by airworthiness standards, is the fact that the landing gear properties are determined at the early stages of the aircraft engineering, when many data are approximate or not determined. At the initial stage of the engineering, depending on the airplane target performance, they define the landing gear layout, the number of legs and the wheels to the leg. These properties primarily are the following: landing and takeoff weight, the speed envelope at takeoff and landing, the basing conditions (at the artificial or unpaved aerodromes). Once the landing gear concept is determined, the structural arrangement of the landing gear is designed, the pneumatic tires and shock absorption performance are selected: the travel rate of the shock absorber piston, the volume of the gas chamber and the pressure in it, the hydraulic resistance at the shock absorber extension and compression, etc. Based on the computation of the aerodynamic performance of the aircraft the maximum horizontal speeds at landing are determined. The weight and CG envelopes determine the aircraft reduced weight, falling on each landing gear leg. Apart of the landing impact, all the limit loading cases, formalized in the airworthiness standards, are addressed as well. The outcome of the computation of the external loads is a magnitude of forces, applied on the landing gear leg wheel axle. These loads are the reference ones to determine the reactions at the landing gear attachment fittings to the aircraft structure and select the dimensions of the landing gear structural elements.

As far as the aircraft engineering is proceeded, the estimates may be detailed, accordingly, the loads may be specified along with the landing gear design. As to the RRJ-95 aircraft there had been no change to the landing gear design since the early engineering, when the ultimate loads had been determined for the landing gear designer. This had only been the verification analysis carried out to the legs integrity that had validated their compliance to the integrity requirements.

As stated by the aircraft designer and the certification authorities, there is no correlation between the AR-25 item 25.721 requirements and the limit and ultimate design loads, referred to at the engineering and the assessment of the landing gear structure integrity. Item 25.721 does not establish a comprehensive list of the design cases to demonstrate the safe separation of the landing gear legs and does not impose requirements to the magnitudes of loads, for which the compliance shall be demonstrated.

The third touchdown occurred with the acceleration of 5.0G at least, the estimated vertical speed amounted to 6.1 m/s. As the consequence of the collapse of the Attachment A structural elements «weak links» at the second touchdown the load-bearing structure of the landing gear legs had not been locked, that is they had been positioned non-normally, which is supported by the following:

- as per the FDR record after second touchdown all the wheels to the MLG legs rotated at the same speed and deceleration; after the third touchdown the right inboard wheel continued to rotate, whereas the others stopped;

- the inspection of the spot of the third touchdown revealed the presence of traces of the right engine nacelle, the pneumatic tire to the right outboard wheel and the flange to the left inboard wheel; the inspection of the left inboard wheel flange revealed that it had sustained damage, that is to say the touchdown had fallen on it.

Eventually, the MLG legs had not been capable to absorb the loads out of the third landing impact. With that the absorbed energy had exceeded the magnitude for the design loads by about 2.8 times (for a vertical speed at touchdown of 3.74 m/s), with that the landing loads acted directly on the elements of the aircraft structural elements that were not designed for their action. According to the general «philosophy» of the structural integrity certification, under the loads of the kind, having been higher against the ultimate ones, any part (element) of the aircraft, including the fuel tanks could «legitimately» disintegrate.

The outcome of the third touchdown had been the following:

– the destruction of the upper panel, caps and the web to the right wing box forward spar under the vertical load out of the pylon attachment fittings to the forward spar;

– the destruction of the web and the upper cap of the left aft spar, adjacent to the landing gear crossbeam attachment;

– the further destruction of the MLG legs attachment elements;

– the destruction of the webs of the right and left aft spars adjacent to the landing gear legs retraction/extension actuating cylinders and the caps;

– the fuel spillage through the multiple ruptures of the wing box with its further ignition.

In this manner at the third touchdown there occurred the multiple ruptures of the wing box structural elements and the loss of the structural integrity of the wing box. This had been a consequence of the off-design loads effect at the aircraft touchdown with the high vertical speed (going beyond the conditions of landing on a partially extended landing gear or on the retracted landing gear, stated in CRI) right on the engine nacelles and fuselage.

Note: ***CRI C-04 EASA***

In showing compliance to CS 25.561, 25.721 and 25.994, the following interpretative material is an acceptable interpretation:

1. The aircraft has to be designed to avoid ruptures that could be catastrophic for the safety of the occupants, including ruptures leading to fuel spillage under the following conditions:

1.1 Impact at 5 fps vertical velocity at maximum landing weight:

with all gears retracted;

with any one or any two gears retracted.

Hence the investigation team broadly concludes that:

- the consequences of the second touchdown comply to the requirements of the AR-25 item 25.721, as there had been no destruction of the wing box, that would lead to the depressurization of the fuel tanks – these had been the Attachment A fuse pins to be destructed at no fuel spillage;

- the consequences of the third touchdown cannot be assessed in terms of compliance to the Aviation Regulations (Airworthiness Standards), as they go beyond the expected operational conditions, so far as the examination of the consecutive impacts (after the destruction of the landing gear structure) is not required;

- at the standardization of the airworthiness and establishment of the acceptable methods of the compliance demonstration to the standards there is no correlation between the current standards of the landing gear structural integrity and the requirements to the demonstration of its safe destruction (separation). Only minimum requirements are imposed on the integrity of the landing gear structure, there are no requirements to the largest possible certification ultimate safety margins, the structure can be «remeasured»/reevaluated as much as desired. Alternatively, at the demonstration of the MLG legs safe destruction (separation) feature there are no minimum requirements, under which the safe destruction shall be demonstrated, with that the maximum magnitudes of loads are not particularly limited. The mentioned circumstances lead to the fact that at the compliance demonstration to the AR-25 item in practice (in operation), at the aircraft «allocation» outside the conditions, which had been taken to confirm compliance to the indicated item, the risk of the fuel tanks destruction with the fuel spillage and the fire eruption hazard remains fairly high;

Note: *On the results of the investigation of the air accident to the RRJ-95 RA-89011 aircraft on October 10, 2018*[178] *the Safety Recommendation had been issued that the aircraft designer «in cooperation with the certification authorities consider practicability of introducing alterations to the landing gear design and/or introducing the equivalent measures to mitigate the risk of the fuel spillage onset consequently to the landing gear exposure to the loads, exceeding the design ones». As communicated by the designer, at the time of the Report drafting the activities on the addressing of the respective risks mitigation are in progress.*

- the synthesis of the results of the investigation to the event under consideration and several other air accidents (to the RRJ-95 aircraft, MSN 95032 (registration 97006) on July 12, 2018[179], to the RRJ-95 RA-89011 airplane on October 10, 2018, to the B777 G-YMMM aircraft on January 17, 2008[180] and to the B737 VQ-BPS airplane on February 9, 2020[181]) reveals that:

- in all instances at the first landing impact the landing gear structure had operated as assigned, having prevented the disintegration of the fuel tanks. At neither occurrence there had been the complete separation of the MLG legs;
- the fuel tanks disintegration up to the point to constitute the fuel spillage enough for the fire onset (in the modern interpretation of this notion) had been the occurrence in three events out of five (the RA-89011, G-YMMM and RA-89098);
- out of three mentioned occurrences with the fuel tanks disintegration, two cases[182] (the RA-89011 and G-YMMM) had been the consequence of the «uncontrolled» action of the damaged - but not separated - structural elements to the landing gear MLG legs into the continued aircraft movement, as for one event (the RA-89098) – it had been the result of the «inappropriate» control inputs by the crew, having led to another landing impact;

[178] The Final Report is published by the link: https://mak-iac.org/upload/iblock/087/report_ra-89011.pdf.
[179] See Section 1.18.18 of the Report.
[180] See Section 1.18.23 of the Report.
[181] The Final Report is issued by the link: https://mak-iac.org/upload/iblock/11c/report_vq-bps.pdf.
[182] To these occurrences the actual circumstances of the first landing impact had been substantially different from the design cases, addressed at the certification.

- in two events, having not implied the fuel tanks disintegration, the actual circumstances of the first landing impact are very alike the design cases, addressed at the certification. Along with that after first landing impact, having resulted in the destruction of the «weak links», the actions by the crew had been either absolutely correct (MSN 95032, registration 97006), or the crew had not have time to accomplish any important actions (VQ-BPS).

2.3.4 The evaluability to control the engines and of the other aircraft damage, having been sustained at the hard landing and erupted ground fire

This Section presents the analysis of the serviceability of a number of the aircraft systems and engines into the landing roll. Against the air accident circumstances the information is only stated on those systems that had or could have affected the outcome of the flight and the serviceability of which had not been subject to analysis in the Sections above. For ease of understanding the data are given in the tabular format.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:00	First runway touchdown	IDLE ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE		
15:30:01	Aircraft ground-to-air transition	ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE		
15:30:01.5	Flight	The initiation of resetting of the TL to the REV position ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	As there is no sign «airplane on ground» generated, FADEC does not launch the sequence of the TR doors opening and maintains IDLE. *Note: the sign «aircraft on ground» is generated by the MLG legs WOW data.*	

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:02	Second runway touchdown	TL on the REV MAX detent ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	The sign «airplane on ground» has been generated. FADEC commands the TR control system actuators to open the TR doors. The IDLE engine power rating is maintained as the doors position has not yet reached 65%.	
15:30:03	Aircraft ground-to-air transition, the flight	TL in the REV MAX position ENG MASTER - ON HPSOV open (the fuel is supplied)	IDLE	The TR doors are still opening[183]. FADEC maintains IDLE as there is no sign «airplane on ground» generated.	
15:30:05	The airplane in flight	TL in the REV MAX position ENG MASTER - ON HPSOV - open (the fuel is supplied)	IDLE	At reaching 88 % of the TR doors opening the sign «TR fully deployed» is generated to both engines (Рев1_ВЫП/TR1_DEPL and Рев2_ВЫП/TR2_DEPL).	

[183] The analysis of the designer documentation to the propulsion powerplant with the SaM146 engine was the evidence that it does not incorporate the description of the procedure to control the TR opened doors against the removal of the Airplane on ground sign. The experiment, held by the aircraft designer on the Electronic Bird bench, demonstrated that in this event the TR control system does not actuate the automatic closing of the TR opened doors, but the engine operation mode will be reset on the enforced IDLE.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:06	Third runway touchdown	TL reset to the MAX position (forward thrust) ENG MASTER - ON HPSOV - open (the fuel is supplied)	IDLE	After resetting the TL from the REV range to the forward thrust range the TR doors start to stow. As long as the TR doors are open, irrespective of the TL position, FADEC maintains IDLE. The MLG legs collapse, the airplane is lowered on the engine nacelles. While stowing, the doors reached the positions as follows: the left one ~67% and the right ~27%. The unlocked condition of the doors is due to the damaged TR structural elements after the aircraft lowered on the engine nacelles. The occurrence of the spurious signal on the closing of the left SOV (Топ_КП_дв1_ЗАКР = 1/Fuel_SOV_eng1_CLOSED = 1). Actually the SOV remained open[184].	The fault (to the airframe) of the return cable consequent to the destruction of the cable fastening elements in the MLG leg bay can be considered the probable reason for the occurrence of the signal on the left SOV closing. At that point of time there was no control command (the crew's actions), delivered to the closing (out of ENG FIRE or ENG MASTER switchlights), there was no thermal effect present either.

[184] See Section 1.16.9 of the Report as well.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
Between 15:30:06 - 15:30:12	The aircraft movement on the RWY	TL at the MAX detent ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	Due to the mechanical damage of the thrust reverser elements against the incoming air the TR doors reposition to deployment. ECU to the left propulsion powerplant recorded the failures to the TR control system, caused by the failure of the reverser doors to stow after the TL resetting to the forward thrust range[185]: - DCV or PL Right failed in open position - T/R system failed to stow - Reverse Unlocked - PLU switch failed in unlocked position - PLL switch failed in unlocked position - TLL failed in unlocked position. There are no ECU data for the right propulsion powerplant, but the FDR record (after the aircraft lowering on the engine nacelles) of the parameters: «Уров_отправ_С_дв2 = 1»/«Channel_deliv_C_ENG2 = 1», «Уров_отправ_D_дв2 = 1»/«Channel_deliv_D_ENG2 = 1», «TR2_NOT_STOW = 1» indicates - owing to the similarity in conditions – the similar failures of the TR system, which are recorded for the left engine.	

[185] See Section 1.16.4 of the Report as well.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:12	The aircraft movement on the RWY	TL at the MAX detent ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	The APU inlet temperature and EGT start to increase	At the APU RPM of 100%, the APU inlet temperature at landing was ~21°C, EGT - ~291°C.
15:30:14	The aircraft movement on the RWY	TL at the MAX detent ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	The spurious signal to the closing of the left SOV is no longer active (Топ_КП_дв1_ЗАКР = 0/ Fuel_SOV_eng1_CLOSED = 0)	
15:30:17	The aircraft movement on the RWY	The start of the TL resetting to the REV MAX position. ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	The reoccurrence of the spurious signal to the closing of the left wing SOV (Топ_КП_дв1_ЗАКР = 1/Fuel_SOV_eng1_CLOSED = 1). Actually the SOV remained open. The condition is maintained up to the record end.	

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
Between 15:30:18 - 15:30:33	The aircraft movement on the RWY	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	FADEC maintains the IDLE mode, as the sign «airplane on ground» is not generated.	
15:30:26	The aircraft movement on the RWY	TL in the MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	IDLE	The APU RPM start to decrease	The APU inlet temperature is ~120°C, EGT – ~610°C

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:34	The aircraft movement on the RWY	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the sign «the engine runs» is no longer active by DECU (Дв1_раб = 0 /Eng1_run =0). The right engine on IDLE	The left engine inlet temperature starts to increase against the open flame adjacent to the air intake. Until the record stop the engine inlet temperature value was oscillating over the range of ~70 ˚C - ~80 ˚C. Commanded by FADEC, the low pressure rotor (N_1) and the high pressure rotor (N_2) speed start to decrease to ensure the gas-dynamic stability against the engine inlet temperature increase. The sign «The left engine running» (the Дв1_раб=0/ENG1_run=0 parameter) is removed due to the speed decrease below the limit one for the idle (IDLE) under actual conditions.	The signal Дв1_раб = 0/ Eng1_run =0 is generated, when the engine is not running (shut down) or N_2 decreases below a certain level.
15:30:38	The aircraft stop	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the parameter Дв1_раб=0/ En 1_run=0 The right engine on IDLE	-	

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:30:41	-	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the parameter Дв1_раб=0/ Eng1_run=0 The right engine on IDLE	The signal on the battery BAT4 overheat (the parameter « Перегрев_Бат_4/Overheat_BAT_4»). The battery is installed at the stand at the F5 compartment in the fire affected area.	
Between 15:30:41 - 15:30:53	-	TL in the REV MAX position ENG MASTER – ON HPSOV to the right engine – open (the fuel is supplied) HPSOV to the left engine – see the Analysis column	The left engine is below IDLE, the parameter Дв1_раб=0/Eng1_run=0 The right engine on IDLE	To protect the left engine from the rotating stall FADEC carried out a triple short-time (of the 0.5 sec. duration) closing of HPSOV. The stall, most probably, was induced by the considerable inlet temperature oscillations and the TOT spikes of at the exposure to fire and the open flame penetration adjacent to the air intake. After three unsuccessful attempts to resume operation FADEC should have shut the engine down. This was not done, as there was no sign of the airplane on ground.	

Between 15:30:45 - 15:30:48	-	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the parameter Дв1_раб=0/Eng1_run=0 The right engine on IDLE	1. The failure signal is recorded to the left drive generator (the parameter ОТК_ген_лев = 1/FAIL_gen_left = 1»). The FIRE SW ACTION signal is recorded in the NVM to GCU#1 –L ENG FIRE switchlight pressed at the flight deck[186]. *Note: GCU L by the FIRE SWITCH command shuts off the left drive generator.* The electric supply system reconfiguration. The aircraft left side is powered from the right drive generator. 2. The BAT3 battery overheat (the parameter «Перегрев_Бат_3/Overheat_BAT_3»). The battery is installed at the stand at the F5 compartment in the fire-affected area. 3. The L DC ESS – 3 bus failure (the parameter «27ESS3_НОРМ/27ESS3_NORM»). It is allocated in the DC switchgear # 3 in the F5 compartment in the fire-affected area. 4. The R DC ESS – 4 bus failure (the parameter «27ESS4_НОРМ/27ESS4_NORM»). It is allocated in the DC switchgear # 4 in the F5 compartment in the fire-affected area. 5. Over the time interval of 15:30:25 – 15:30:48 the APU RPM was decreasing from 99% to 0%. The RPM decrease was derived from the reduction of the fuel flow by the APU control unit by the control laws at the increase of the engine inlet temperature up to 320 °C. At the interval end there occurred the APU self-shutdown.	By pressing the L ENG FIRE or R ENG FIRE switchlights, the associated SOV is to be closed as well. At this point of time and further on, the SOV had not actually closed. The mechanical and / or thermal destruction to the SOV power cables may have been the probable cause of the loss of control (the failure to close) of the SOV by the point the ENG FIRE was pressed.
15:30:51	-	TL in the REV MAX position	The left engine is below IDLE, the	The occurrence of the spurious signal on the right SOV closing (it is kept active till the end of the	The right SOV closing signal may have occurred due to the

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
		ENG MASTER – ON HPSOV – open (the fuel is supplied)	parameter Дв1_раб=0/ENG 1_run=0 The right engine on IDLE	record). The post-accident inspection revealed that the SOV remained in the open position[187].	fault (to the airframe) of the return cable due to a thermal effect after the fire onset.
Between 15:30:54 - 15:30:59	-	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the parameter Дв1_раб=0/Eng1_run=0 The right engine on IDLE	1. The failure signal is recorded to the right drive generator (the parameter ОТК_ген_пр = 1/ FAIL_gen_right = 1). The FIRE SW ACTION signal is recorded in the NVM to GCU # 2 –R ENG FIRE switchlight activated at the flight deck[188]. 2. The delivery of the signal on the closed position of the APU SOV, most probably following the release of the APU FIRE switchlight at the flight deck.	By the video footage the lights on the NLG switched off at 15:30:58 – this is the most precise time of the right drive generator shutoff (the lights on the NLG are the second category consumers).

[186] See Section 1.16.6 of the Report.
[187] See Section 1.16.9 of the Report as well.
[188] See Section 1.16.6 of the Report as well.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
15:31:00	-	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	The left engine is below IDLE, the parameter Дв1_раб=0/Eng1_run=0 The right engine on IDLE	The record of the TRU1, 2, 3 failures. The disconnection of all the AC buses, but for the AC INV bus. The disconnection of all the switchable DC buses. Only the first category consumers remain powered that are connected to the non-switchable DC buses and the AC INV bus, powered by the static inverter. The DC buses to the right aircraft side and to the left aircraft side are interconnected.	For the moment these are only BAT1 and BAT2 batteries that remain the available electric power sources, which are installed at the area of the forward service compartment outside of the fire-affected area. The BAT1 and BAT2 batteries ensure the power supply of the L DC ESS – 1 and R DC ESS - 2 buses. The static inverter is powered by the L DC ESS – 1 bus.
15:31:06	The IFDMU, FDR stop recording the flight data.	TL in the REV MAX position ENG MASTER – ON HPSOV – open (the fuel is supplied)	ENG MASTER L in the ON positon. ENG MASTER R in the ON position. The left engine power rating: N_1 = 13.13%, N_2=46.5%. The right engine power rating: N_1 = 28.88%, N_2=79%.	The IFDMU and FDR stopped recording the flight data. It occurred, most probably, due to the AC INV bus power off, as a result of: 1. the static inverter failure or the burnthrough of the electrical wiring between it and the AC INV bus at the exposure to fire, adjacent to FR33. 2. the forced cutoff of the static inverter by the crew (highly improbable). The static inverter cutoff button may have been pressed after the aircraft power off.	At the point of the record stop all four batteries remained switched on.

Time	Event	The TL, ENG MASTER and HPSOV position	Engines power rating	Analysis	Additional information
By the video footage 15:31:10 (after the FDR and IFDMU record end)	The extinction of the right landing light	No data available	No parameters data available, the engines continue running.	The power of the right landing light is enabled by the R DC ESS-2 bus, located in the DC switchgear # 2 in the forward service compartment (FR10). Most likely, the light switched off due to the R DC ESS-2 bus power off due to the activation of the BAT 1 and BAT2 batteries circuit-breakers.	After both generators cut off the R DC ESS-2 and L DC ESS-1 buses were integrated and powered by the BAT 1 and BAT2 batteries. It is likely that the point of the light switch off aligns with the power off of both non-switchable buses consequent to the activation of circuit-breakers because of the short-circuit.
By video footage at 15:31:34 (after the FDR and IFDMU record end)	The aircraft engines shutdown			Of the available means to shut the engines down after the record end and the landing light extinction at 15:31:10 (it indicates the DC buses power off), there was only one left: the transmission of a discrete signal from the ENG MASTER switches to the DECU, by which the DECU closes the HPSOV. Apparently, it was at this moment that the ENG MASTER switches were set to OFF by the crew.	

On the capability of the engines shutdown

As the engines (propulsion powerplants), having run for a long time after the fire eruption, had contributed to its intensive development, the investigation team gave particular consideration to the capability of their shutdown by the crew.

The powerplant control on the RRJ-95 aircraft is enabled by FADEC, which consists of:

- digital engine control unit/DECU;
- fuel metering unit/FMU;
- actuator control unit/ACU;
- engine overspeed unit/EOSU.

DECU is a dual channel unit, at the operation one of the channels is active, whereas the other is a standby one. In case the faults are detected to both DECU it is the «most efficient channel» to operate. After the engine startup the permanent magnet alternator/PMA and the actuator out of the engine accessory gearbox enable the DECU self-sustained power supply. The switching of the electrical power supply from the aircraft buses to the PMA occurs at N_2 above 38%. In this way, at the point of the total aircraft power off in the flight that ended up with the accident, the electric power supply of DECU to both engines should have been maintained, as their N_2 were above 38%.

Fig. 172 presents the engine control (startup and shutdown) panel and the TL quadrant. The engine control panel (engine startup/shutdown) is designed, inter alia, to stop the running engines.

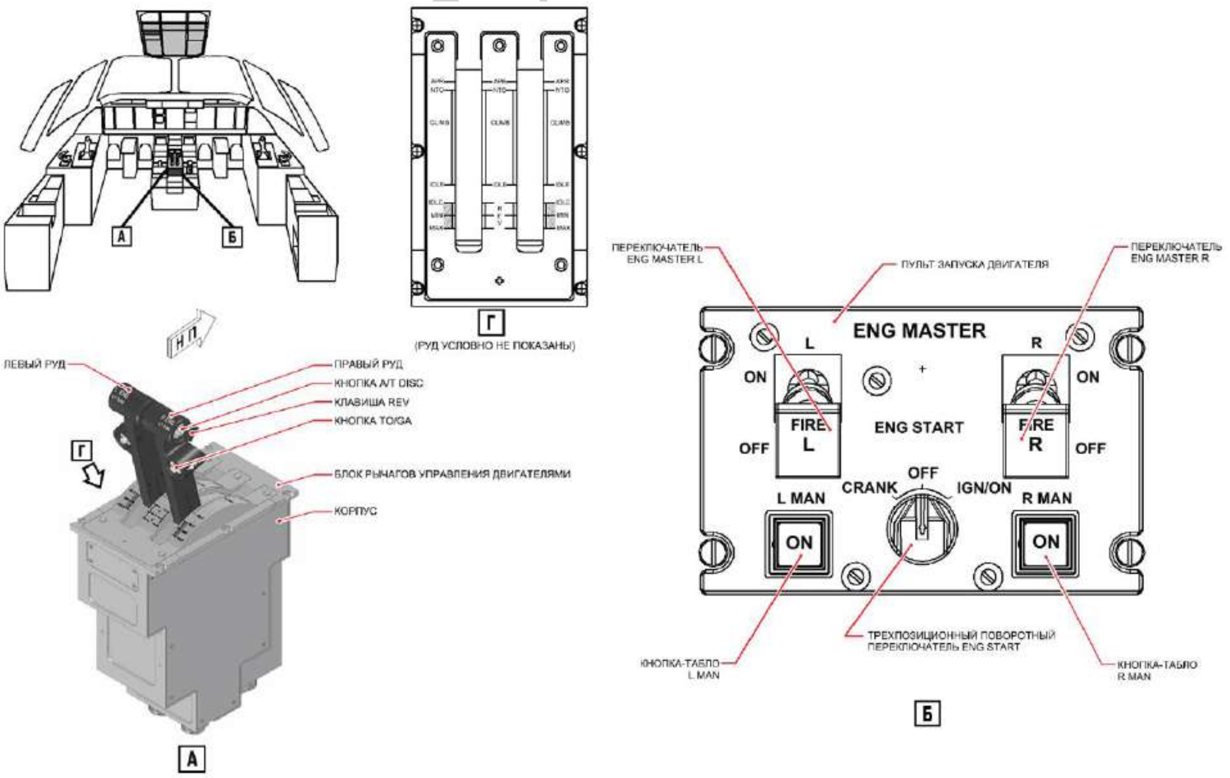


Fig. 172. The layout of the engine control components

The engine fuel system is designed to supply fuel with the required flow, pressure and temperature parameters to the combustion chamber fuel nozzles. The fuel flow shut-off to the engines is accomplished by several means.

To shut the engine down the high pressure shutoff valve/HPSOV interrupts the fuel supply to the fuel nozzles. The HPSOV is an integral part of the FMU, installed on the engine. The switching of the running engine ENG MASTER (Fig. 172) to the OFF position by the pilot commands the closing of the respective HPSOV.

When the crew switches ENG MASTER to the OFF position, the signal to close HPSOV is delivered both from the ENG MASTER switch itself and from DECU, i.e. through two independent interfaces (Fig. 173). The delivery of any signal is enough to have it closed.

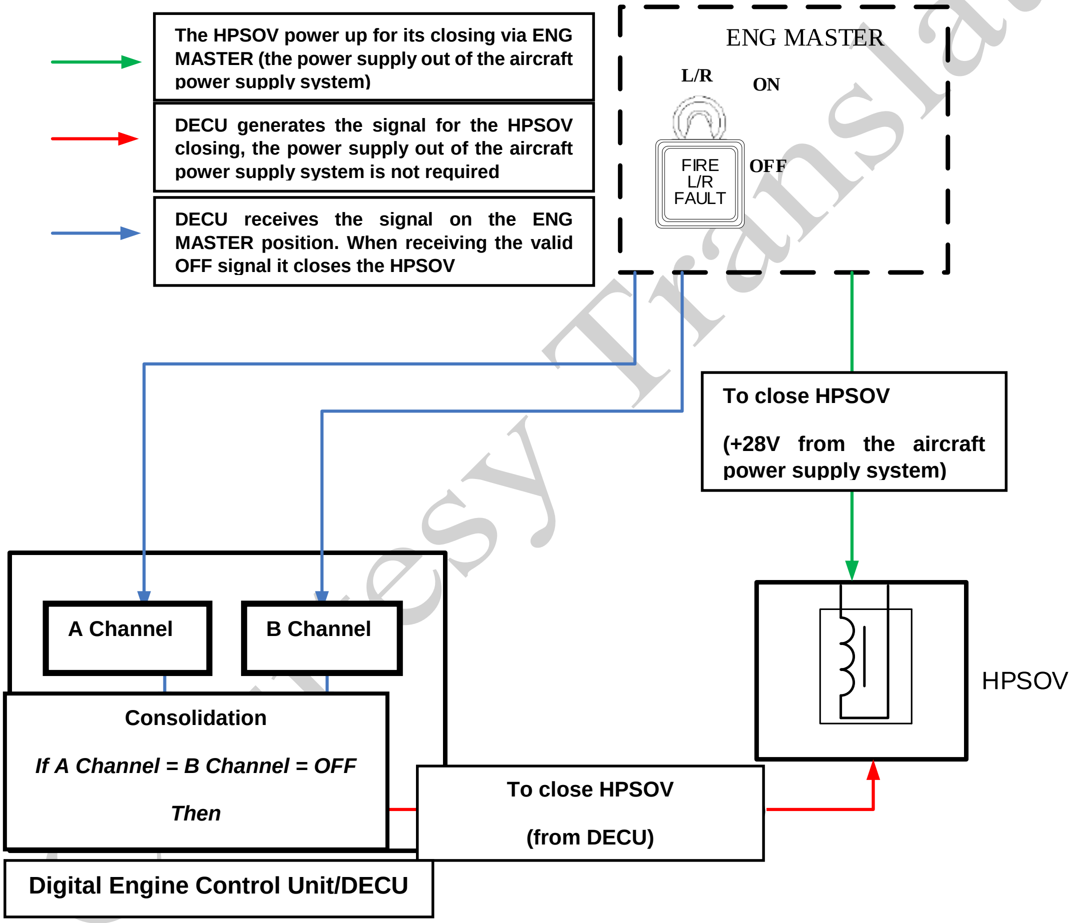


Fig. 173. The schematic of the generation of the command to have HPSOV closed, when switching ENG MASTER to the OFF position

FADEC continuously monitors the HPSOV health. The record of a number of discrete signals is enabled at the FDR, detecting different anomalies both to the HPSOV and DECU. The analysis was the evidence that at the landing and into the landing roll the propulsion powerplants power rating control systems had functioned as assigned. Moreover, as indicated in the Table here above, to prevent the rotating stall at the final landing roll the left engine control system had been temporarily closing the HPSOV three times (the associated discrete signal is recorded by the FDR), in other words the valve had been appropriately controlled, consistent with the design-integrated logic.

Therefore at the time interval, supported with the FDR record, the crew had the capability to shut the engines down anytime by switching the ENG MASTER to the OFF position. There had been no such crew's actions recorded. Until the end of the FDR record the ENG MASTER switches to both engines had remained in the ON position.

According to the available video footage, as well as to the analysis of the fire propagation, adjacent to the exhaust-mixing nozzles, exposed to the jet stream, the stop (shutdown) of both engines occurred virtually simultaneously, at about 15:31:34, that is in 28 seconds after the FDR had stopped recording and in 24 seconds after the aircraft had been completely powered off. The engines had shut down before the arrival of the firefighting vehicles and the initiation of the fire suppressing activities. The analysis revealed that the only way to shut the engines down after the total aircraft power off had been the switching of ENG MASTER to the OFF position by the crew. At the accident site both ENG MASTER switches had been observed in the OFF position (Fig. 20).

The engine control system design ensures that the HPSOV control loop from the ENG MASTER switches via DECU (Fig. 173) remain efficient even at the airplane total power off, as with the running engine it is powered by the DECU self-sustained power supply, which in turn is powered by the PMA. This shutdown loop is to function every time, irrespective of the presence/absence of the airplane on ground signal. In the course of the investigation the efficiency of this method in the accident flight environment had been confirmed by the direct experiment on a real airplane.

The second way to shut the running engine down is to close the wing SOV that interrupts the fuel supply out of the fuel tanks to the engine. In normal operation the SOV closing occurs at the ENG MASTER switching to the OFF position or at the pressing of the ENG FIRE switchlight. Both ways imply that there is a power supply on the respective aircraft buses. In fact after the air accident both SOV had been retrieved in the open condition (see Section 1.16.9 of the Report). The SOV had not actually closed as prior to the aircraft power off there had been no ENG MASTER switching to the OFF position by the crew, and by the point of the ENG FIRE switchlights activation the respective communication lines to the SOV sustained damage, exposed to the off-design mechanical loads and/or the fire, which rendered the closing of the SOV by this way impossible.

In the progress of the analysis, carried out by the investigation team, all the other scenarios of shutting the engines down had found no evidence either. For instance the investigation team studied the scenario of the engines shutdown, consequent to the running out of fuel out of the wing fuel tanks compartments of the left and right outer wing (see Section 1.18.16 of the Report). It had been determined that after the FDR record stop the values of the actual fuel consumption and of the remaining fuel in the wing fuel tanks compartments only (excluding the potential of their refilling, including from the other cells by gravity) indicate that the fuel should have been enough for more than 14 minutes, which is significantly longer than the actual running time of the engines before shutdown.

2.4. The analysis of the established procedures and the ATC officers' actions[189]

The factual information on the ATC personnel can be found in Section 1.5.3 of the Report. It states as well the time intervals, when the RA-89098 aircraft had been under the control of a particular ATC officer. Through this Section, unless otherwise stated, the ATC officer/controller term refers to the ATC employee, under whose control the aircraft had been within the reviewed time interval.

State ATM Corporation, FSUE Computer-Aided ATC Moscow Center branch Sheremetyevo ATC center (hereinafter referred to as the Center) and the Moscow Air Hub ATC center were compliant to the requirements, set out in the FAR «The requirements to legal entities, providing air navigation services to the Russian Federation airspace users aircraft air operations. The form and procedure for issuing a document to confirm the compliance to the specified requirements», approved by the Ministry of Transport Order # 216 of July 14, 2015.

The air operations supervisor, the shift senior controllers and the ATC personnel to the Center shift # 1 and the Moscow Air Hub ATC center shift # 5, who carried out the ATC, met the qualification requirements, set out by the FAR «Requirements to the air traffic controllers and paratroopers-instructors», approved by the Ministry of Transport Order # 216 of November 26, 2009.

The professional training, the recurrent advanced training and the authorization to perform duties as to the ATM personnel in the Center and Moscow Air Hub ATC center were carried out compliant to «The operation of the continuing system of professional training, including the personnel certification, internship, the procedure for authorization to perform duties, the recurrence of the advanced training to the management and ATC personnel», approved by the Ministry of Transport Order # 93 of April 14, 2010.

The traffic capacity standards in the Center are determined according to FAR-293 items 2.3.6 and 2.3.7. The composition of the Center and Moscow Air Hub ATC center shifts, having

[189] In this Section only these ATC officers' actions have been subject to analysis that are pertinent to the circumstances of the flight that ended up with the accident.

been involved in the air navigation to the aircraft of the AFL1492 flight, allowed to ensure ATM at the control units (sectors) of the Center and Moscow Air Hub ATC center subject to the requirements of «The Regulations on the peculiarities of the duty and rest time of the employees – air traffic controllers to the Russian Federation civil aviation», approved by the Ministry of Transport Order # 10 of January 30, 2004. The duty time of the ATC personnel, who carried out the ATM, as well as the procedure of the personnel backup for rest met the requirements of the mentioned Regulations. The air traffic density had not exceeded the published values of the traffic capacity standards for the control units (sectors).

The R/T phraseology at the radio communication with the crew of the AFL1492 flight had been generally in line with the requirements, set out in FAR «The procedure to carry out radio communication in the Russian Federation airspace», approved by the Ministry of Transport Order # 362 of September 26, 2012.

On the results of watching the video footage of the briefing room, as well as by the analysis of the other data it has been identified that the Center air operations supervisor carried out the briefing to the shift within 10:40:25 - 11:05 strictly according to the procedure sheet. As a part of the briefing the report by the Roshydromet Head Aeronautical Meteorological Center, FSFI Sheremetyevo branch forecaster on duty was heard with the weather radar data display on the monitor (these to the weather surveillance radar and the TDWR), the ring weather chart, the data by the weather satellites.

On the results of watching the video footage of the briefing room, as well as by the analysis of the other data it has been identified that the Moscow Air Hub ATC center air operations supervisor carried out the briefing to the shift within 11:13:08 - 11:23 strictly according to the procedure sheet. The forecaster on duty, the Moscow Air Hub ATC center engineer and shift senior controller’s reports were heard.

As per the control rooms CCTV data from the point of the radio contact initiation by the AFL1492 flight crew the controllers were allocated at their duty stations and were not distracted from ATM.

In accordance with FAR-60 Chapter IV item 83 and the Instruction on the air operations meteorological support at Sheremetyevo aerodrome, approved by the Sheremetyevo International Airport, JSC operations general manager first deputy on January 23, 2019, the aerodrome meteorological authority (the Head Aeronautical Meteorological Center branch) is to provide the aircraft crews with the latest obtained information, including the data by the weather radars (the Doppler weather and the weather surveillance radars) that are displayed at the monitor screens at the briefing facilities.

Still according to the Aeroflot, PJSC OM the flight weather documentation is to be handed out to the airline crews by the Aeroflot, PJSC staff forecasters. As per the available information the airline forecasters, who drafted the weather documentation, had the opportunity to review the TDWR data, but the TDWR data (the graphic images on the display of the thunderstorm activity zones, etc.) were not directly communicated to the aircraft crew.

Within the time interval of 14:56 - 15:03 the aircraft had been under the control of the Center Tower C1 sector ATC officer. According to the Tower C1 sector ATC officer SOP, his area of responsibility covers, inter alia, the aerodrome maneuvering area, including RWY1 and RWY2, bounded by the holding points lines; the airspace within a radius of 10 km off the Moscow (Sheremetyevo) aerodrome ARP, limited below by the ILS obstacle clearance surface up to the altitude of 600 m QFE (exclusively) except for the approach sector. The control transfer line to the Sheremetyevo Radar sector Radar controller at takeoff: the point the airborne aircraft crosses the altitude of 600 m QFE or when it reaches the distance of 10 km off the ARP within the takeoff sector, whichever comes first.

By the point the aircraft enters the receiving Tower controller's airspace this ATC officer is to forecast the air/traffic environment within the ATM sector based on the analysis of the routine data and the current position of the departing and arriving traffic, identified either visually in sight or with the use of the NOVA 9000 A-SMGCS, Topaz ATC automated complex and the other available means, as well as, when required, by monitoring the radio communication by the controllers to the adjacent control units (sectors) (as per the Tower Sector C1 ATC officer SOP item 5.2.1.1).

Before issuing clearance for takeoff the Tower controller is to relay the information on the change of the weather conditions to the aircraft crew (as per the Tower Sector C1 ATC officer SOP item 5.2.2.1), and, in line with the criteria, published in the AIP of the Russian Federation (Book 1, AD2.1 UUEE-30.4.), on the onset of adverse atmospheric conditions, including the thunderstorm (with or without precipitation), hail, whirlwind, squall.

Fig. 174 presents the exterior of the Tower Sector C1 controller duty station. The Tower controller may choose the meteorological conditions information be displayed either on the Topaz ATC automated complex screen (Fig. 175), or be obtained right from the KRAMS Integrated Aerodrome Radiotechnical Weather Station display (Fig. 176), which is installed above the controller's duty station. The meteorological information is updated every minute.

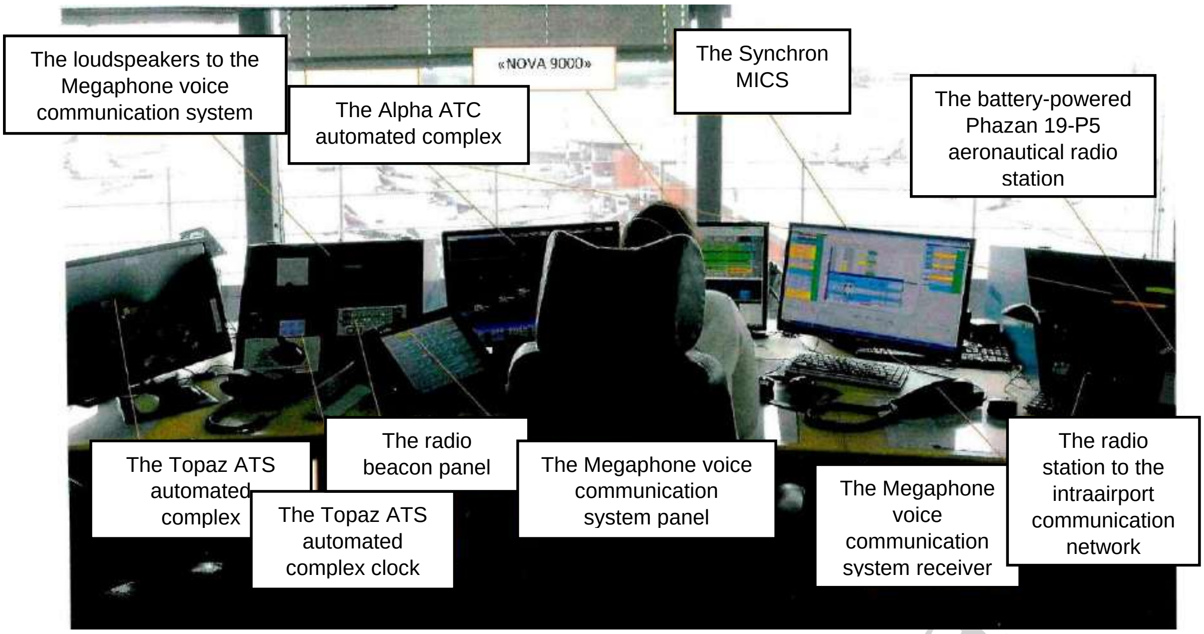


Fig. 174. The exterior of the Tower C1 sector controller's duty station

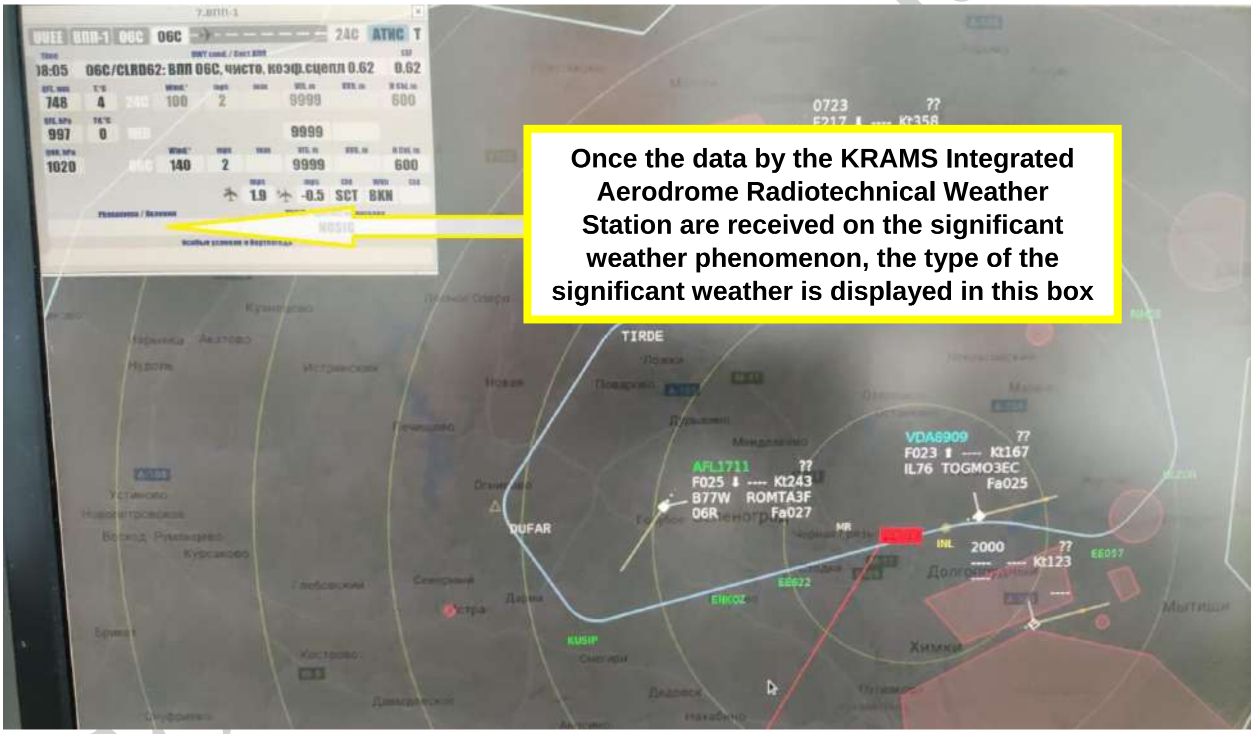


Fig. 175. The example of the KRAMS Integrated Aerodrome Radiotechnical Weather Station box display on the Topaz ATC automated complex screen (the radar environment and weather data do not apply to the flight that ended up with the accident)

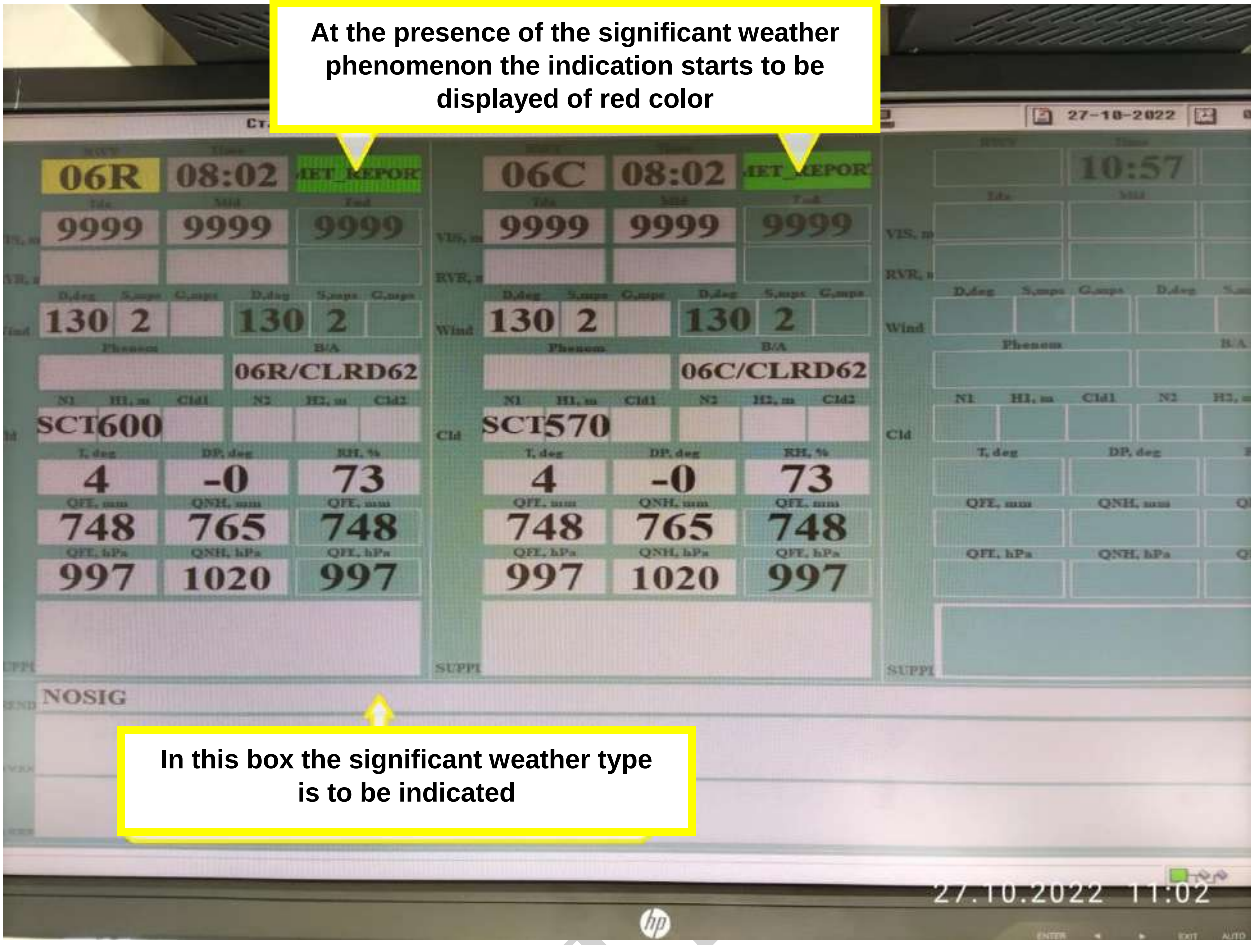


Fig. 176. The example of the KRAMS Integrated Aerodrome Radiotechnical Weather Station screen display (the weather data do not apply to the flight that ended up with the accident)

At 15:02:23 the controller cleared takeoff to the crew, relaying the up-to-date information on the surface wind. At the point the takeoff clearance was issued, the warning information on the significant weather, including thunderstorm, was not displayed on the KRAMS Integrated Aerodrome Radiotechnical Weather Station screen, as there was no thunderstorm at the aerodrome. Accordingly, the actions by the Tower C1 Sector controller in the instant case complied with the SOP provisions.

The investigation team points out that as per the FAR-293 item 5.3.21 the ATS authority does not relay the information on the meteorological conditions aboard the aircraft prior to takeoff in the knowledge that the aircraft has already received the data of the kind. The similar provisions are stated in the SOP (before takeoff the controller is to relay aboard the information on the change of the meteorological conditions only).

Note: ***The FAR-293 item 5.3.21***

Before takeoff, the aircraft is to be relayed the information about changes in the meteorological conditions: the direction or velocity of the surface wind, visibility, runway visual range or air temperature (for the jet engines aircraft), as well as the presence of thunderstorms or cumulonimbus clouds, moderate or strong *turbulence, windshear, hail, moderate or severe icing, severe squall line, freezing precipitation, severe mountain waves, sand or dust storms, general drifting snow, tornado or whirlwind in the aerodrome (air hub) area, except when it is known that this aircraft has been already relayed this kind of information.*

However, as a rule, the controller is not aware, which is the latest information on the meteorological conditions the crew has been relayed. This way, for instance, in the reviewed case the crew had not reported this information when having established the radio contact with the Tower controller. The controller, for his part, had not requested to communicate it (it is not required by SOP). Hence, commonly, it is not possible for the controller to identify these ***changes*** of the meteorological conditions, which he is to inform the crew of. Generally, when issuing clearance for takeoff, the controller routinely relays the current wind force and direction, in some cases the RVR.

Within the time interval of 15:03 - 15:07 the aircraft was flown under the control of the Sheremetyevo Radar + Sheremetyevo Approach unified Radar sector. There were two controllers, performing their duties at the sector: this of the radar control (it was he to carry out the control and radio communication with the crew) and this to the procedural control.

Note: *The duty shift air operations supervisor to the Moscow Air Hub ATC center made the decision to combine the sectors at the low-intensity period of air traffic and the ATS controllers' workload (23 aircraft from 15:00 till 16:00 at the declared value of the traffic capacity standard at the Sheremetyevo Radar + Sheremetyevo Approach Radar sector of 47 aircraft, max. – 56).*

Compliant to the Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller SOP item 3.1. the sector area of responsibility at the aircraft takeoff covers, to the RWY 24C inter alia, the SID within established geographical boundaries above 450 m AMSL (above 300 m AGL) up to the ATM control transfer FL (Radar-Approach)[190] inclusive, except for the area of responsibility of the Sheremetyevo aerodrome Tower. The ATC control transfer point from the Tower sector C1 controller: *«after takeoff from Sheremetyevo aerodrome to the aircraft in climb that perform flight above 300 m AGL ... in the area of responsibility of the Sheremetyevo aerodrome Tower or the crossing of the indicated area of responsibility geographical boundaries (whichever comes first) ».*[191]

Fig. 177 shows the Radar controller's duty station. It is possible for the controller to choose the option of the radar environment display, combined with the TDWR information, on the Syntez-

[190] At the day of the accident it had been the FL70.
[191] The stated control transfer point does not fully correspond with this, indicated in the Tower C1 sector controller SOP (see earlier in the text). This shortcoming had not anyhow affected the outcome of the flight.

AR4 ATC automated complex. When choosing this option, the TDWR information is continuously displayed (appears on the screen), at that, due to the peculiarities of the TDWR operation, the information is updated once every 10 minutes. As per the available information at the performance of the ATM to the AFL1492 flight the TDWR data had been displayed to the Radar controllers.

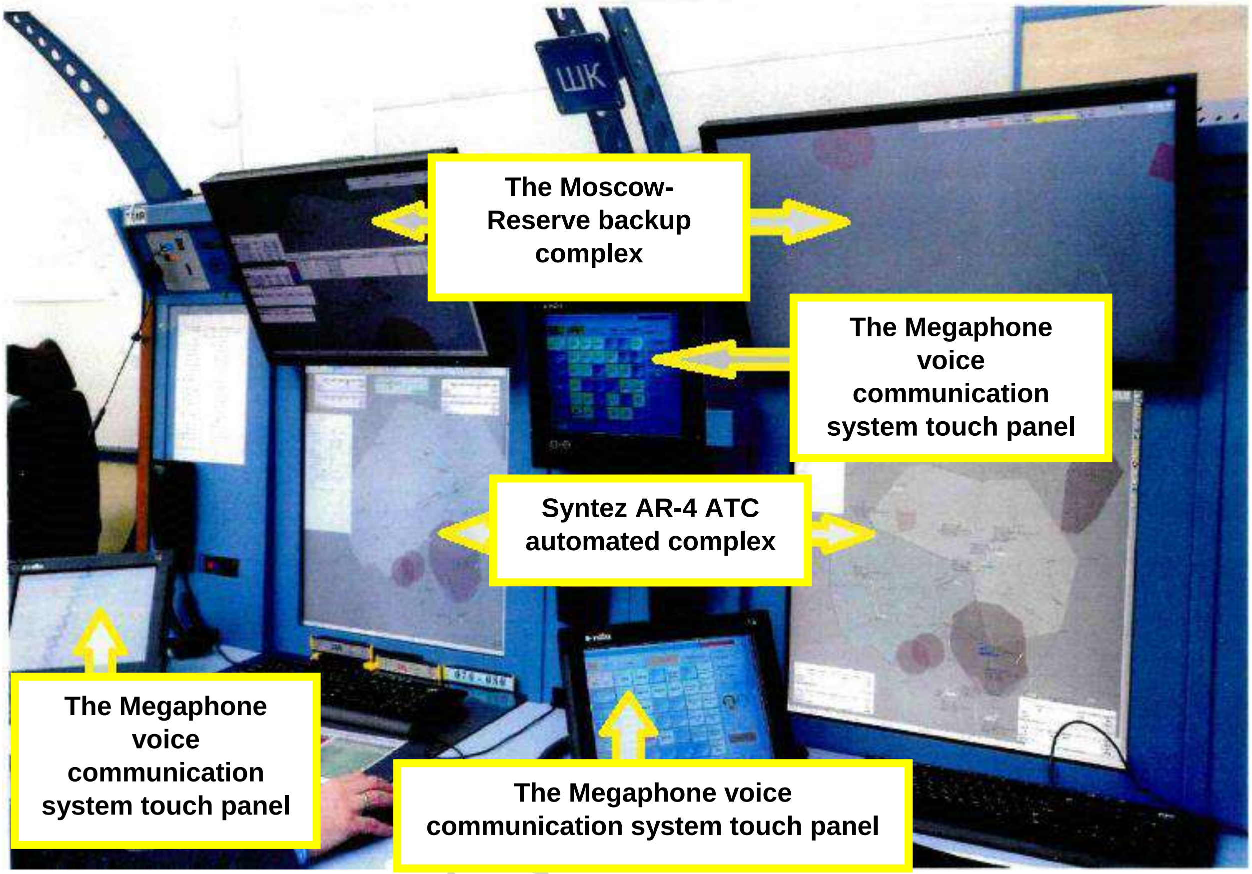


Fig. 177. The exterior of the Radar controller's duty station (the radar control officer to the left, the procedural control officer to the right)

The radar environment, combined with the TDWR indication, at the points of receiving the aircraft for control and the control transfer is presented on Fig. 178 and Fig. 179. Over preceding 10 minutes before receiving the aircraft for control the controller had been relayed six requests by three different aircraft for the avoidance of the thunderstorm cells[192]. The TDWR «image» changed at 15:05.

[192] See Section 1.18.1 of the Report as well.

Fig. 178. The SYNTEZ-AR4 ATC automated complex indication at the Radar controller’s duty station at 15:03:59 when receiving the AFL1492 flight for control (the aircraft data block is outlined with the red rectangle)

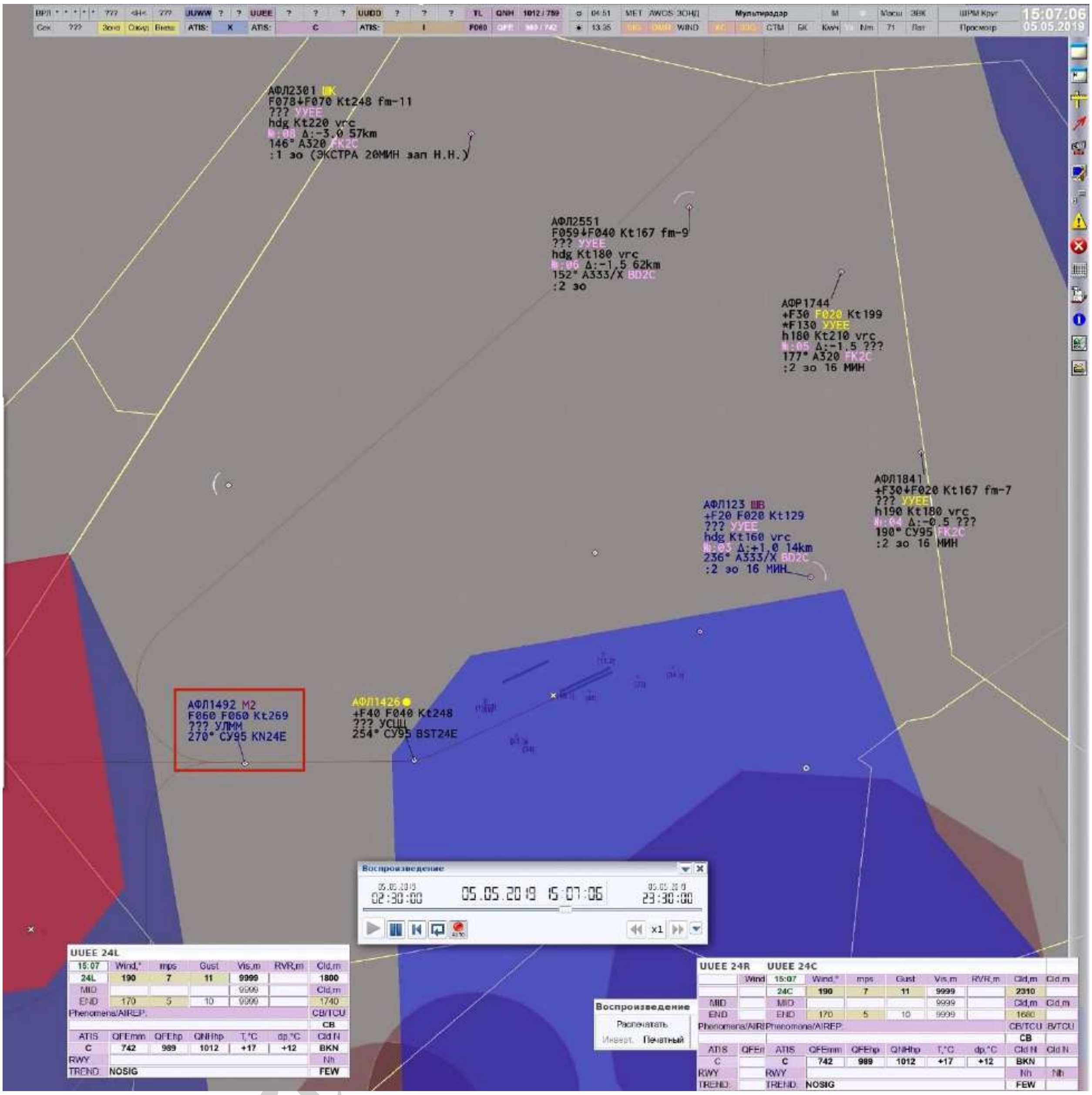


Fig. 179. The SYNTEZ AR-4 ATC automated complex indication at the Radar controller's duty station at 15:07:06 at the transfer of the AFL1492 flight for control (the aircraft data block is outlined with the red rectangle)

In compliance to the SOP Chapter 5 «The peculiarities of the air traffic service» item 5.2.3, after takeoff and establishing the radio contact by the crew the radar control officer, among other things, shall inform the crew on the presence of *«the adverse atmospheric conditions in the sector (as required)»*. This item of the SOP does not define any responsibilities of the procedural control officer in presence of the information on the adverse meteorological conditions.

As per the SOP item 6.2.3 that determines the actions by the radar control and procedural control officers in presence of the information on the adverse meteorological conditions in their area of responsibility and at the ATM transfer points, the radar control officer: *«shall brief the aircraft crews about the areas with the adverse atmospheric conditions, request the decision by the aircraft crews on the avoidance of the areas in the question on the basis of the information by* *the meteorological engineer, the SIGMET data, the weather radars data at the ATC automated complexes and the data, relayed by the aircraft crews*». These actions had not been taken by the radar control officer. Although there were the data on the thunderstorm activity in his area of responsibility, including in the immediate vicinity to the estimated flight path of the aircraft (the KN 24E SID), the radar control officer had not communicated the respective information to the aircraft crew. The stated item of SOP does not impose any responsibilities on the procedural control officer to monitor the radar control officer's actions as for the aspect in question and inform him.

Under these circumstances the stated shortcoming had not been decisive as far as the crew's situational awareness is concerned as to the presence of thunderstorm activity zones (the crew had been able to observe these zones at the aircraft weather radar display, see Sections 2.2.2 and 2.2.3 of the Report). Still «the excess» reminder to the crew that there had been thunderstorm activity zones ahead of the aircraft and the relaying of the information on the avoidance maneuvers by the other traffic could have affected its decision on the necessity and the time of the avoidance initiation.

The said item 6.2.3 to the SOP sets out as well that the radar control officer *«shall analyze the actual weather environment to determine the potential to perform air operations or the necessity to impose restrictions (prohibitions) on their performance».* On Fig. 179 one can see that, while proceeding by the KN 24E SID, the aircraft was dangerously approaching the thunderstorm activity zone. The RA-89098 aircraft crew, unlike the other aircraft, had not requested the avoidance of the zone. The investigation team is of the opinion that the Sheremetyevo Radar sector radar control officer, guided by the indicated item, could have briefed the crew appropriately and suggested the options of avoidance. In fact the radar control officer had shown passivity.

Within the time interval of 15:07 - 15:12 the aircraft had been proceeding the flight under the control of the Approach M2 sector controller. There were two controllers, performing their duties at the sector: this of the radar control (it was he to carry out the control and radio communication with the crew) and this to the procedural control. According to the Approach M2 sector controller SOP item 3.1., the sector area of responsibility covers, inter alia, the segment of the airspace within the established geographical coordinates above the ATM transfer level (radar-approach) up to FL120 inclusively.

Fig. 180 shows the Approach controller's duty station (the equipment identity and names are similar to these on Fig. 177).

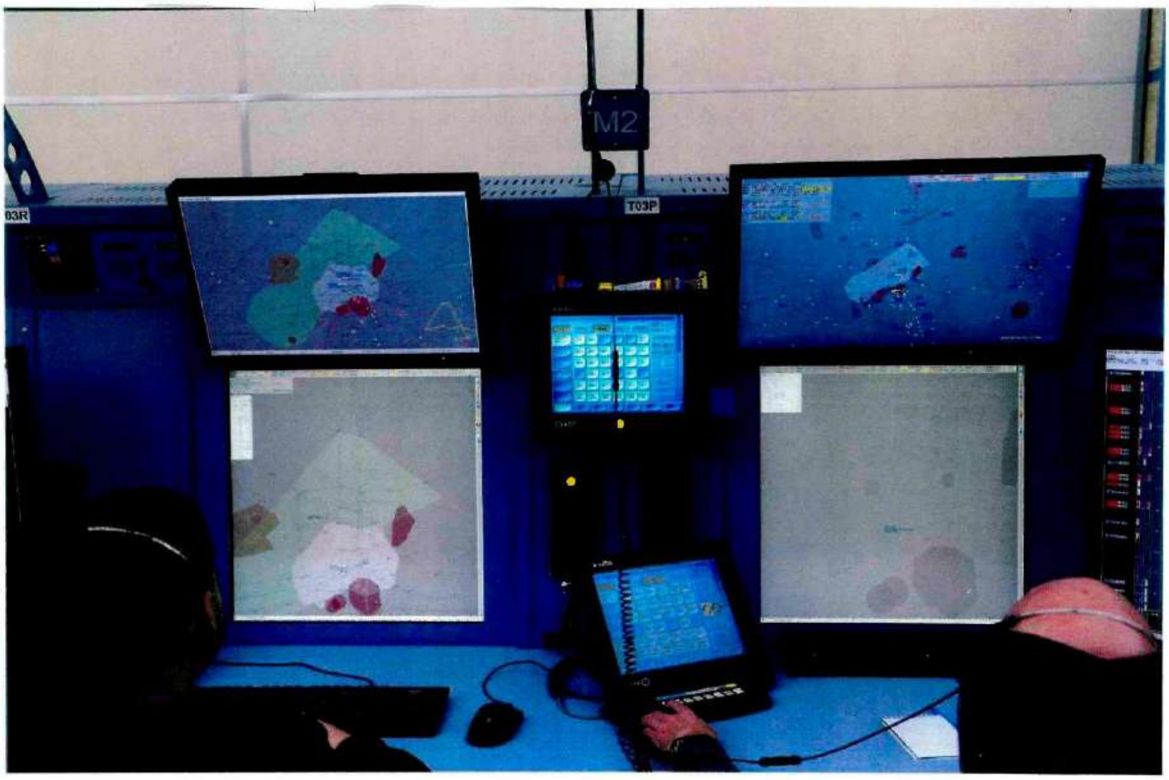


Fig. 180. The exterior of the Approach controller's duty station (the radar control officer to the left, the procedural control officer to the right)

Reportedly, at the ATM of the AFL1492 flight the TDWR data had been displayed to the Approach controllers. The aircraft position at the encounter the atmospheric electricity is shown on Fig. 181. Compliant to SOP (items 5.2.4 and 6.2.3), the required actions by the radar control officer at the M2 sector in terms of briefing the aircraft crews on the hazardous weather phenomena zones are the same as these by the Radar controller. Equally, the said provisions of the SOP had not been fulfilled by the Approach controller. The controller had been unengaged.

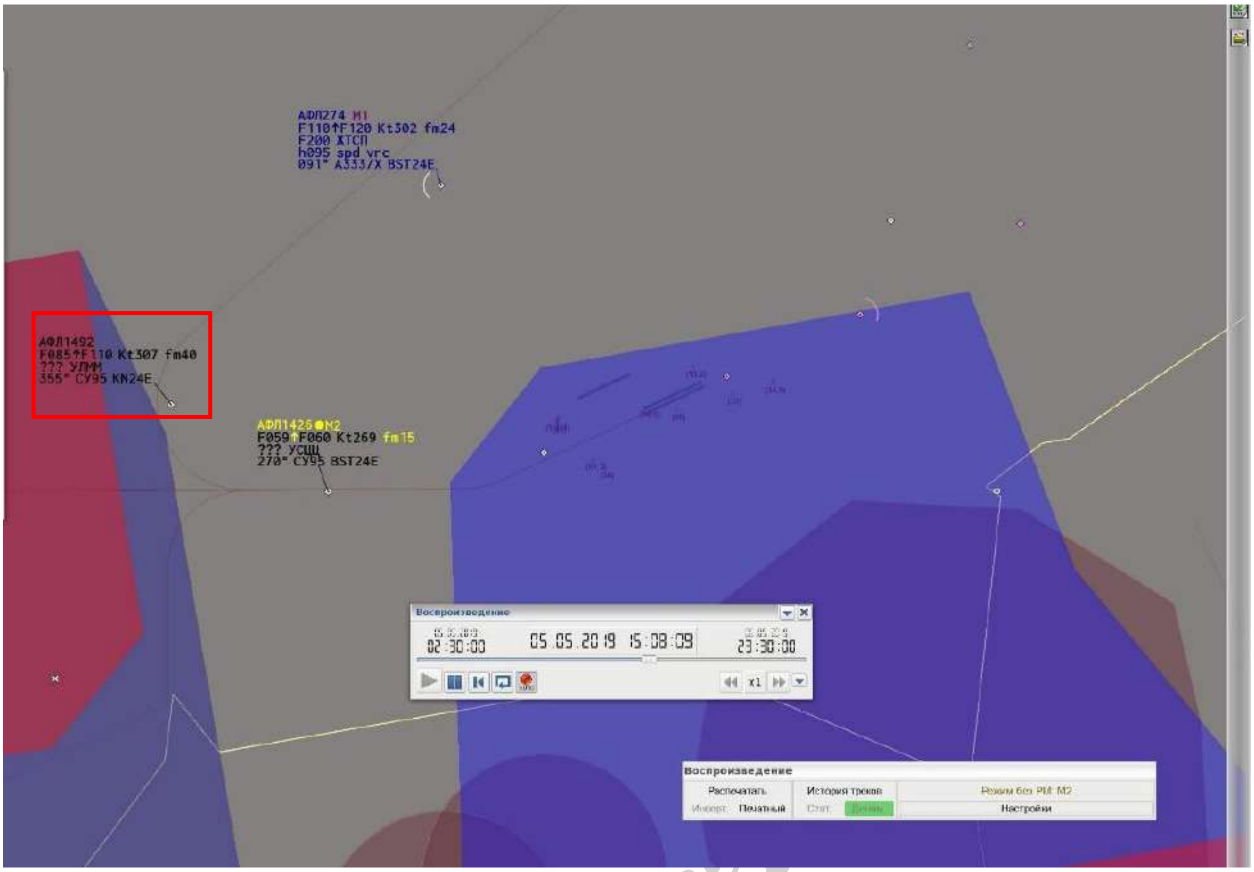


Fig. 181. The SYNTEZ AR-4 ATC automated complex indication at the Approach controller's duty station at 15:08:09 at the AFL1492 flight encounter the atmospheric electricity (the aircraft data block is outlined with the red rectangle)

In this manner the radar control officers to the Sheremetyevo Radar + Sheremetyevo Approach and Moscow Air Hub ATC center M2 sectors had not briefed the AFL1492 flight crew on the thunderstorm situation, the avoidance of the thunderstorm cells by the crew to the other aircraft in the ATC sectors area of responsibility. Having the information on the presence of the thunderstorm activity zones, while the aircraft had been flown on the KN 24E SID, the crew had not been suggested that the avoidance should be performed. The stated controllers' actions did not meet their SOP provisions.

According to the job description, the senior controller (or the air operations supervisor) to the Moscow Air Hub ATC center, when being reported that the additional coordination should be held is to undertake coordination and brief the personnel to the respective ATC sector on the conditions of the airspace use for the performance of avoidance maneuvers of the adverse atmospheric conditions zones. As the AFL1492 flight crew had not relayed requests for avoidance, the coordination of this maneuvers had not been required.

At the point the aircraft encountered atmospheric electricity (15:08:09.7) it had been under the control of the Approach M2 sector controller. There had been neither reports on the impossibility to proceed by the KN 24 E SID due to the thunderstorm activity, nor the requests to avoid the thunderstorm cells, nor the communication on the aircraft encounter atmospheric electricity discharge or the entrance in the increased atmospheric electricity zone by the aircraft crew.

Note: *On being reported by the aircraft crew on the aircraft encounter the atmospheric electricity discharge or the entrance in the increased atmospheric electricity zone the radar control officer shall record the position, altitude, the time of the event, report it to the senior controller (air operations supervisor).*

After the aircraft encountered atmospheric electricity there had been a failure of the onboard VDR1. The first successful radio contact after encounter the atmospheric electricity was established on the 121.5 MHz emergency frequency with the use of VDR2 at 15:09:04: *«Sheremetyevo-Tower, Aeroflot 14-92, how you read? »* (see Section 1.18.26 of the Report as well). This sentence can be heard at the recorders to the control units. The Approach controller tried four times to respond to the crew on the 122.7 MHz operating frequency (with that the crew went on with the requests on the emergency frequency, which were not delivered to the controller). The two-way radio communication was resumed not earlier than at 15:09:35, when the controller responded on the emergency frequency. Thus, over about half a minute the controller was not able to identify the fact that the crew conducted the radio communication on the emergency frequency and respond accordingly that could have further increased the crew's psychoemotional tension.

Note: *The controller with the use of the Megaphone voice communication system can concurrently monitor several frequencies. It is possible to adjust the volume of the messages as to each of the monitored frequencies. The messages may be distinguished, that is to say it is possible to identify the specific frequency, the message is relayed on, by the voice communication system panel indication.*

At 15:09:29 the aircraft crew on the 121.5 MHz emergency frequency relayed the PAN-PAN urgency signal *« PAN–PAN, PAN–PAN, PAN–PAN, Aeroflot 14-92».* At 15:09:34, after the crew set the 7600 squawk code, at PPI the PC (radio loss) mode is activated in the AFL1492 data block, whereas at the screen to the SYNTEZ AR-4 ATC automated complex in the AFL1492 flight data block there appeared the БР (Radio Loss) status (Fig. 182).

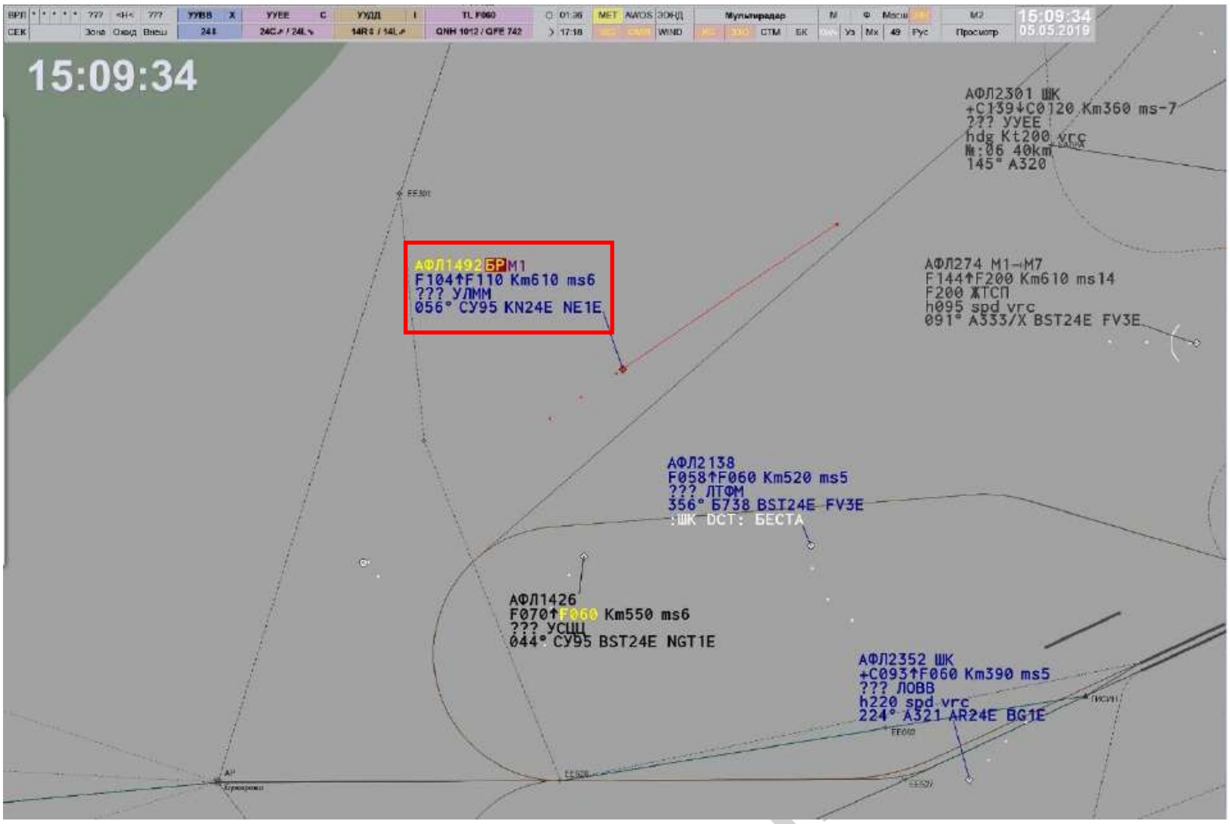


Fig. 182. The SYNTEZ AR-4 ATC automated complex indication, the point of the change in the data block status (it is outlined with the red rectangle) to the AFL1492 flight, the activation of the БР/Radio Loss mode[193]

The controller's actions at the radio communication failure are stated in the SOP item 6.3.7.5. Compliant to this item, the radio communication is considered lost/failed if, within 5 minutes, at the use of the available radio communication channels, the crew (controller) does not respond to the numerous calls on each of them and / or the 7600 squawk code or the БР/Radio Loss sign is displayed. Practically by the point of the appearance of the 7600 squawk code and the БР/Radio Loss sign the two-way radio communication had been resumed, that is to say there had been no necessity for the controller to carry out the associated procedures, provided for by the SOP.

However, the investigation team observes that the SOP do not integrate the procedures to the case the radio communication with the aircraft was resumed after the setting of the 7600 squawk code. Among other things there is no guidance for the controller on the necessity to remind the crew of the removal (cancellation) of the respective squawk code and assign the new one to it. The situation of the kind may establish certain risks. This way, for instance, the information transmission to the crew at the performance of the radio communication failure procedures does not imply the acknowledgment of its receipt, whereas under normal procedures this is a mandatory requirement.

[193] On this Figure the TDWR data have been removed for the ease of perception.

Thereafter the radio communication was conducted on the emergency communication channel (frequency), the controller carried out the aircraft vectoring.

At 15:11:56 the controller instructed the crew that they contacted the Radar controller: *«Aeroflot 14-92, descent to flight level 6-0, contact Sheremetyevo-Radar sector*.

Over the time interval of 15:12 - 15:27 the aircraft proceeded the flight under the control of the Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller (the same radar control and procedural control officers, as before). In accordance with the Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller SOP item 3.1., the sector area of responsibility at the arrival of the aircraft covers, inter alia, the STAR, the RNAV STAR, the approach patterns in the established geographical boundaries above 450 m AMSL (above 300 m AGL) up to the level of the ATM transfer (radar-approach) inclusively, except for the Sheremetyevo aerodrome Tower area of responsibility. In Section 3.3 the ATM transfer point is determined from the M2 sector Approach controller: the reaching of the ATM transfer level (radar-approach).

After receiving the aircraft for control, the Sheremetyevo Radar + Sheremetyevo Approach radar control officer carried out its vectoring to ensure its descent and approach.

At 15:13:51 the controller requested: *«…will any assistance be required? »*, to which the crew replied negative: *«… No, so far everything is fine, as assigned …»*. Hence the ATC officers at that point did not have reasons to initiate any additional actions to support the aircraft approach and landing.

At 15:14:43 the Center air operations supervisor informed the Sheremetyevo International Airport, JSC shift supervisor: «*The AFL 1492 after takeoff reported as follows: the radio communication loss and he has just said that there is no automatic control to the aircraft, at that it is approaching, now is turning base, approaching by the base turn for landing. As for the approach and landing themselves, they were declared as assigned, but still I'm going to call the Air Operations Search Emergency and Rescue Support Service and make them aware. So well the AFL1492 after takeoff made the decision to return to us to Sheremetyevo*», to which the Sheremetyevo International Airport, JSC shift supervisor acknowledged the receipt of information: *«I got that it is approaching as assigned, copied*». Later on the air operations supervisor communicated the same information to the emergency and rescue response leader.

At this stage the 7600 squawk code remained set on the transponder. The crew continued to conduct the radio communication on the emergency frequency and at 15:18:53 requested the holding area over the KN point at the controller: *«AFL1492, a holding spot over Kilo November, if possible»*. The analysis of the record to the ATC recorder revealed that this sentence, transmitted on the emergency frequency, is audible, still heavily «crammed» with the radio communication on the operating frequency with the other traffic.

The controller did not respond to the request. Most probably he did not grasp this request, as at that time he was conducting radio communication with the crew to the KAR389 flight (at 15:18:52 the KAR389 crew: *«KAR389, now can I request the heading (illegible) for avoidance? »*, at 15:19:02 the KAR389 crew: *«Say again, KAR389»*, the controller at 15:19:03: *«KAR389, turn right for avoidance»*). There had been no other requests by the RA-89098 aircraft crew to the controller to perform the holding procedure over the KN point.

Over 15:21:37 - 15:22:34 the Sheremetyevo International Airport, JSC shift supervisor and the Center air operations supervisor discussed whether the Alarm signal of the Green code should be declared. Notably, the following conversation was recorded: « *[The Center air operations supervisor name and patronymic], shall we declare the code to it?* », to which he was replied: «*Well he does not declare emergency. I'm not even sure. The radio communication failure is not a reason to declare the Green code*[194]*, but I would rather call [the emergency and rescue response leader name and patronymic] just in case and make him aware about such a possibility for the personnel are on standby*». The airport shift supervisor replied: «*I got it, all right*». Reportedly, this call took place but there had been no actions taken on the Air Operations Search Emergency and Rescue Support Service workforce and means high-alerting.

Note: *Compliant to item 10.3.1. of the Sheremetyevo International Airport, JSC Emergency Response plan (ПЛ-2.3-02-15 (version-1), enacted by the Sheremetyevo International Airport, JSC Order # 267 of May 25, 2016, the Alarm signal of the Green code (the midair aviation incident) is to be declared in the following instances:*

- *the receipt of the message on the upcoming landing of the aircraft in distress for the cases:*

a) the inflight aircraft engine(s) failure;

b) the loss of stability, controllability, the impairment of the aircraft structural integrity;

c) the aircraft onboard fire;

d) the radio communication loss;

e) the aircraft emergency descent;

f) the aircraft landing at the landing gear failure and the destruction of the wheel tyres;

g) the hydraulic system failure;

[194] The note by the investigation team – as a matter of fact, as indicated in the Note below through the text, the radio communication loss is one of the reasons to declare the Green code Alarm signal.

- *at the sudden deterioration of health or injury to the aircraft flight crewmembers (passengers);*
- *in the other cases, as requested by the PIC.*

The investigation team indicates that the ATC officers still did not have hard sufficient reasons to declare the Green code Alarm signal (despite the 7600 squawk code, remaining active), as the aircraft crew was then conducting the radio communication with the ATM authorities, transmitting the information, receiving and acknowledging the instructions, at that it did not declare emergency.

The Radar controller carried out the aircraft vectoring to ensure the ILS approach. The FAR-293 item 6.10.2 sets out that: *«Aircraft vectored for final approach should be given a heading or a series of headings calculated to close with the final approach track. The final vector shall enable the aircraft to be established in level flight on the final approach track prior to intercepting the specified or nominal glide path, and should provide an intercept angle with the final approach track of 45 degrees or less»*. Item 6.10.4 specifies: *«An aircraft vectored to intercept a pilot-interpreted final approach aid shall be instructed to report when established on the final approach track. Clearance for the approach should be issued prior to when the aircraft reports established. Radar vectoring will normally terminate at the time the aircraft leaves the last assigned heading to intercept the final approach track».* With that item 6.7.4 prescribes that *«when the aircraft vectoring terminates the ATS authority shall instruct the crew to resume the aircraft navigation on its own, relaying the aircraft position to it …».*

The last heading, assigned by the controller, was 170°, that is it was different from the landing heading (244°) for more than 45°, at that the controller did not instruct the crew on the vectoring termination. The crew established on the heading of 170° at 15:22:30. After short-time flight with that heading the crew continued the turn to the right without the respective instruction by the controller, with no report to him. The controller did not draw the crew's attention to the performance of the unauthorized maneuver by the aircraft, subject to vectoring. Eventually it was the early aircraft turn to the heading, close to the landing one, and the aircraft was proceeding the flight far to the right off the localizer equisignal zone, which required the controller interference at 15:24:09: *« Aeroflot 14-92, if you are planning to capture the localizer, you should proceed to the left for about 20 degrees».* Thereby at the performance of the vectoring procedure the Sheremetyevo Radar + Sheremetyevo Approach radar control officer allowed a number of deviations off the SOP, which, accompanied by the unfounded actions by the crew on the performance of maneuvers without the ATC instruction, resulted in the crew increased workload as it should have performed the additional turn to the landing heading.

At 15:26:18 the Radar controller transferred the crew to the Tower C2 sector controller: *«Aeroflot 14-92, azimuth 63, the distance to threshold 14, contact Sheremetyevo Tower 131 decimal 5»*). The Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller SOP (item 3.3.3.1) the control transfer point for the arriving aircraft is determined as: *«on the final approach, at the distance off the active runway threshold not less than 12 km and no more than 20 km at the lateral offset of the final of not more than 5 km»*.

Note: *The «on the final approach» phraseology, applied in the SOP, does not correspond with the conventional understanding of the stage in question that begins from the FAF (FAP) and is actually under the responsibility of the Tower controller.*

In this way, the point of the control transfer as related to the aircraft position met the established requirements, at that the Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller SOP do not determine the aircraft flight altitude value at the point of the control transfer. FAR-293 in the determination of the vectoring procedures to track the aircraft out to the navaid to ensure the final approach does not establish requirements to the aircraft flight altitude at the stop of vectoring either. There is only a mention that the final approach track interception shall ensure the glide path interception from below, at that, unless the vectoring terminates, the aircraft shall maintain the altitudes, assigned by the controller. FAR-293 does not incorporate the clarifying provisions that can be found in the ICAO Doc 4444 item 8.9.4.2: *«when issuing clearance for approach the aircraft shall maintain the last assigned altitude of flight till the interception of the approach pattern specified or nominal glide path. If the ATS authority requires that the aircraft intercepts the glide path at the altitude, different from the level flight segment altitude, indicated at the ILS approach chart, the ATS authority shall instruct the pilot to maintain this specific altitude unless the aircraft intercepts the glide path»*.

Effectively, the last instruction on the flight altitude that was given by the controller and followed by the crew, applied to the descent down to the altitude of 600 m QFE, whereas the glideslope interception altitude as per the chart (Fig. 29) is 500 m QFE. At that the ILS approach chart provides for the aircraft descent down to the glideslope interception as early as on final from the distance of 14-15 km to the RWY entry threshold. Consequently in each particular flight the indicated segment of the aircraft flight can be proceed under the control of both Radar ATC officer and of the Tower C2 sector. The mentioned ambiguities may result in the crossing of the glideslope line at the altitude of 600 m QFE, which was the case in the flight that ended up with the accident. This fact had not anyhow affected the outcome of the flight.

By contrast, according to the Sheremetyevo Radar + Sheremetyevo Approach sector Radar controller and the Tower C2 sector controller established areas of responsibility, the Radar controller had not been subject to any restrictions as for the assignment of the 500 m QFE altitude to the crew. Meanwhile there had been no requirement on the control transfer at the altitude of the glideslope interception either.

Note: *Compliant to the Tower C2 sector controller SOP, his area of responsibility is the airspace in the approach sector from the distance of 20 km to the RWY thresholds, limited below by the ILS obstacle clearance surface up to the altitude of 600 m QFE (exclusively) or up to the altitude, set out by the approach chart.*

At 15:26:30, when the aircraft was flown at the distance of ~ 13 km off the RWY 24L, the aircraft set the 7700 squawk code. At that the crew was able to establish the radio contact with the Tower C2 sector controller not earlier than at 15:27:34 (see Section 1.18.26 of the Report for details). Essentially the emergency squawk code was set at the stage of the control transfer, with that as for the 7700 code setting the crew did not notify of it either the Radar controller, or the Tower C2 sector one[195].

After the setting of the 7700 code the indication in the AFL1492 data block on the Radar controller's SYNTEZ AR-4 ATC automated complex screen changed from БР/Radio Loss to БД/Distress (Fig. 183). After the crew was transferred to the Tower controller, the Radar controller had to make sure by monitoring the radio communication that the radio contact between the crew and the Tower controller had been established. At the reviewed stage of flight the two-way radio communication had not been established, in other words, the control transfer had not actually occurred. The Radar controller might not have noticed the change of indication (status). With that the investigation team points out that it were only two letters to change in the data block, whereas the display on the red background remained unchanged. The indication of the kind does not have an attracting effect (keeping in mind it had been for a long time by then that the controller had observed this «red background»), and as of the day of the air accident the SYNTEZ AR-4 ATC automated complex had not been equipped with the sound alert to draw the controller's attention to the change of the flight status.

[195] See Section 2.2.4 of the Report as well.

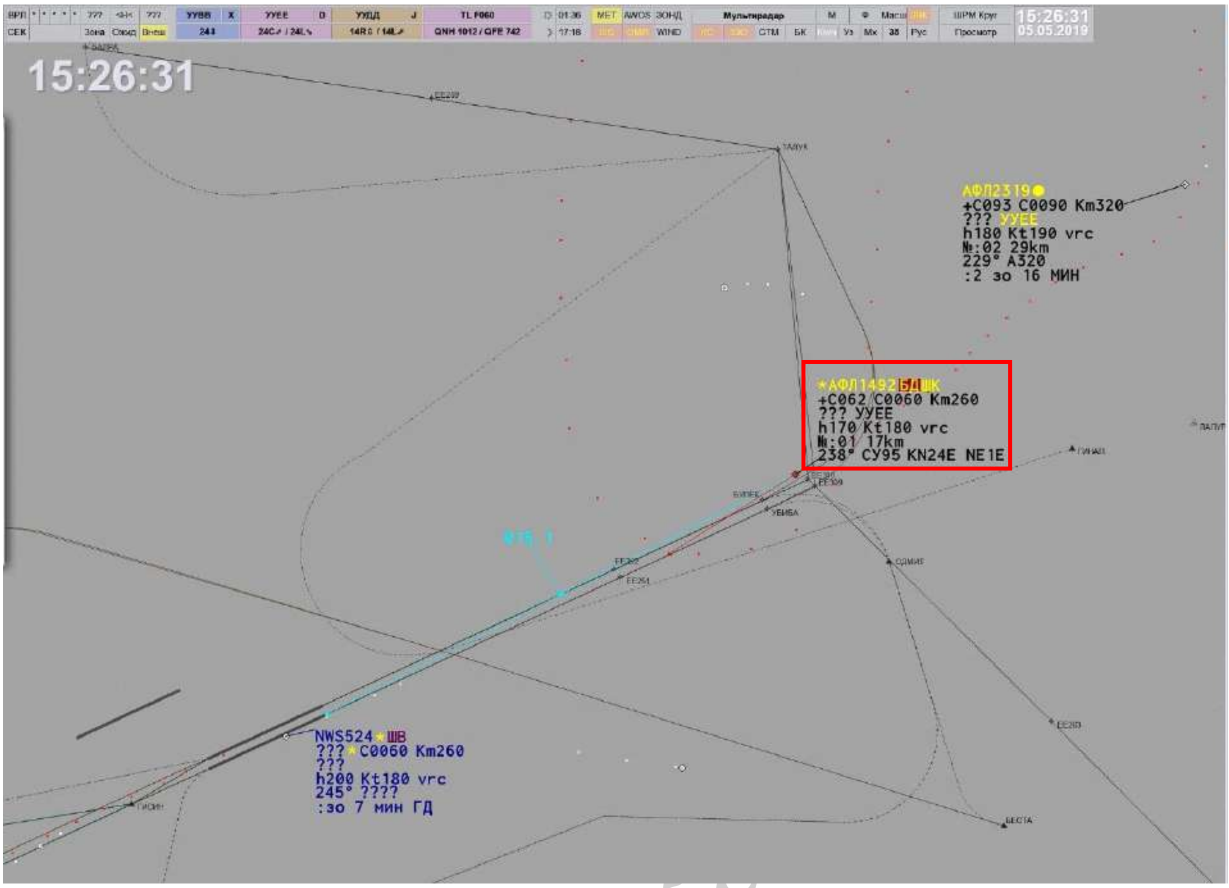


Fig. 183. The SYNTEZ AR-4 ATC automated complex indication, the point of the data block status change (it is outlined with the red rectangle) to the AFL1492 flight, the activation of the БД/Distress mode

Fig. 184 shows the exterior of the Tower C2 sector controller's duty station.

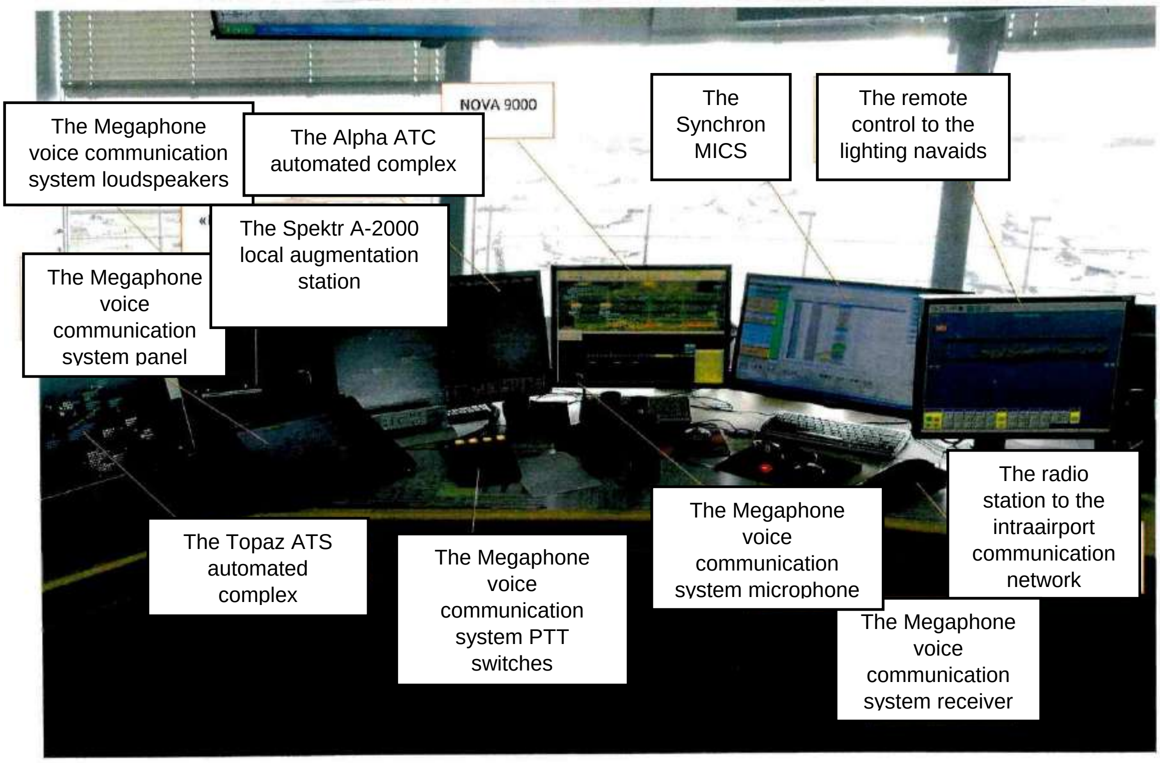
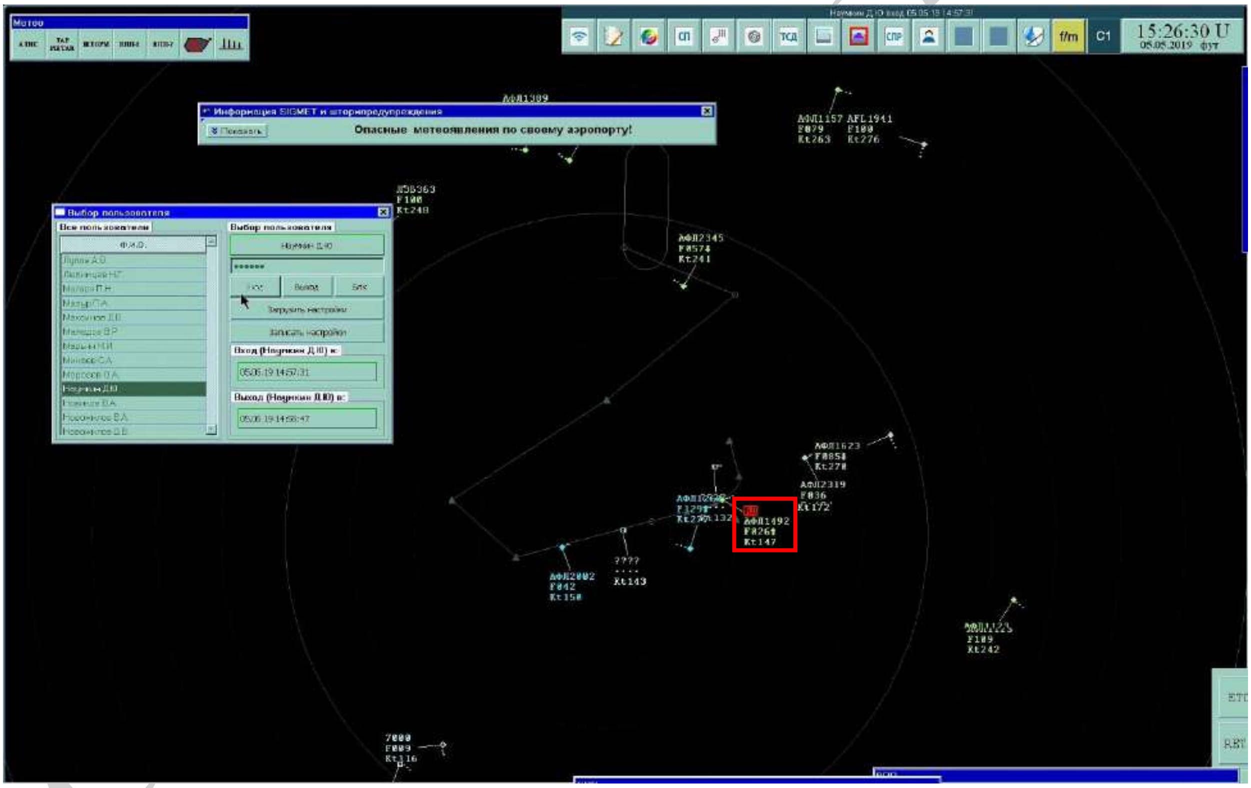


Fig. 184. The exterior of the Tower C2 Sector controller's duty station

After the 7700 squawk code was set at the PPI to the Topaz ATC automated complex the status of the data block to the AFL1492 flight changed from the БР/Radio Loss mode to the БД/Distress (Fig. 185). In the data block on the NOVA 9000 A-SMGCS airfield surveillance radar indicator the status should have been changed from the RCF mode (Radio Communication Failure) to the EMG (Emergency) mode. Indeed, in fact, initially there were two statuses displayed concurrently - «EMG, RCF» (at the entrance in the radar coverage zone, when the 7600 squawk code was set) (Fig. 186), and later, after the setting of the 7700 squawk code, there were three statuses, simultaneously displayed - «EMG, RCF, HIJ» (Emergency, Radio Communication Failure and Hijacking) (Fig. 187), consistent with three different squawk codes («7700», «7600» and «7500»). This presentation is a non-normal one, it had not been possible to determine the reason for such operation of the NOVA 9000 A-SMGCS airfield surveillance radar. Three statuses remained simultaneously displayed till the aircraft landing and after the landing changed to the «EMG» symbol.



a)

b)

Fig. 185. The Topaz ATC automated complex indication, the point of the data block status change (it is outlined with the red rectangle) to the AFL1492 flight, the activation of the 7700 БД/Distress mode; a) the shot of the entire radar display b) the data block

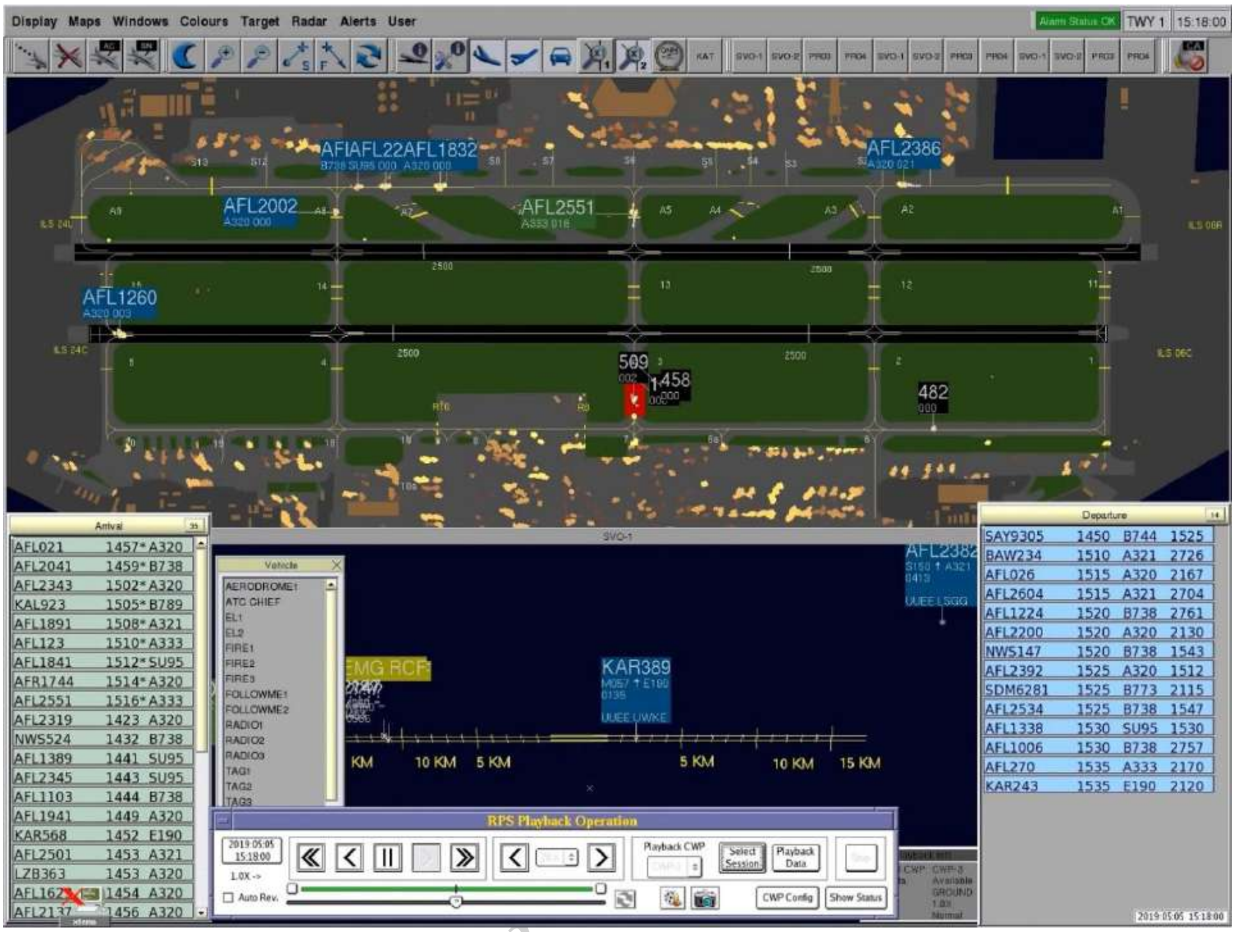


Fig. 186. The NOVA 9000 A-SMGCS airfield surveillance radar indication, the point of entrance of the AFL1492 flight (it is highlighted on a yellow background) in the radar coverage zone (the time of 15:18:00)

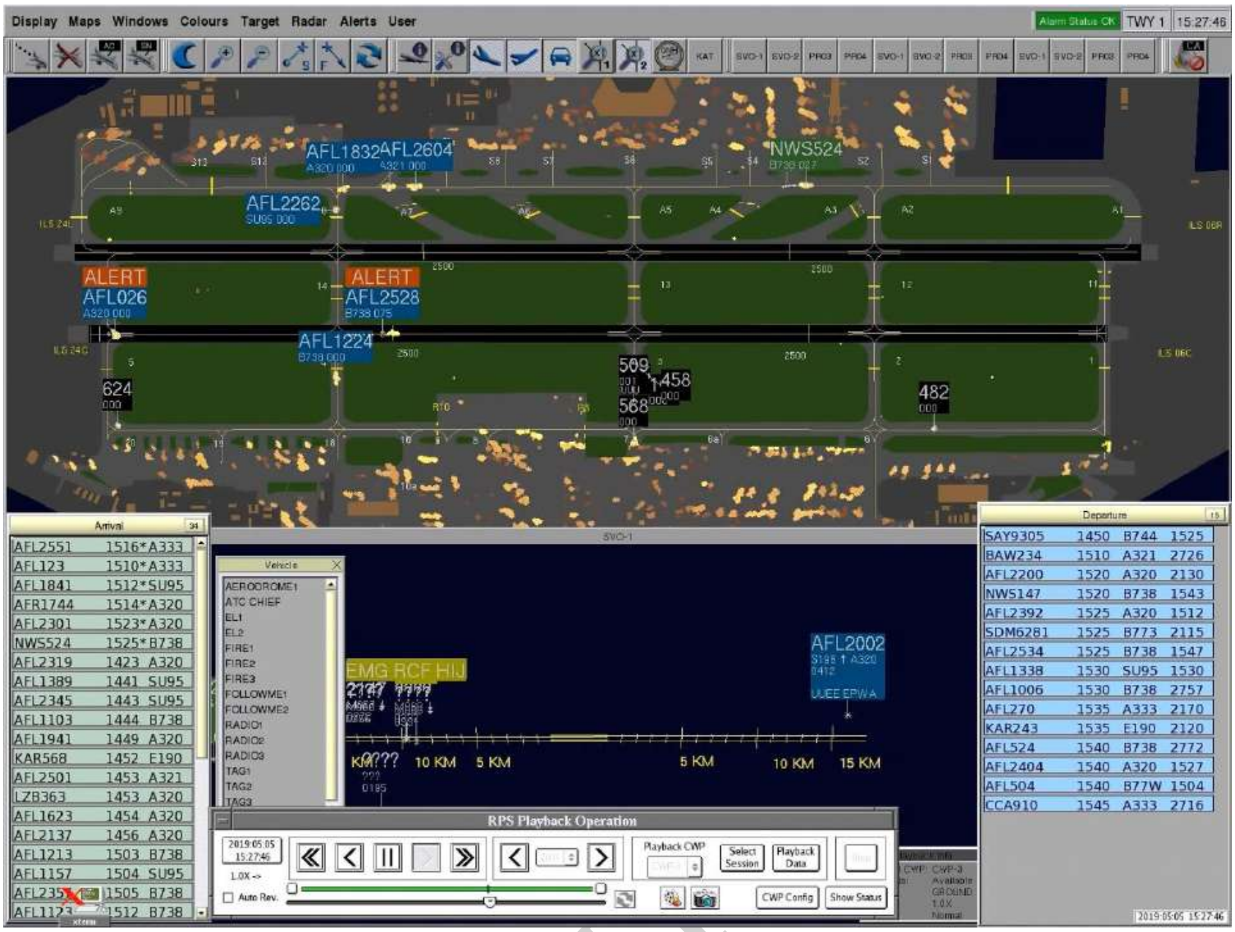


Fig. 187. The NOVA 9000 A-SMGCS airfield surveillance radar indication of the data block (it is highlighted on a yellow background) to the AFL1492 flight at the aircraft glideslope descent (at 15:27:46)

Similar to the Radar controller, the Tower ATC officer neither responded to the change of the status in the data block, nor requested the crew on the reasons of the 7700 squawk code setting, nor reported the conflicting information in the NOVA 9000 A-SMGCS airfield surveillance radar data block to the senior controller or the air operations supervisor. In this way the Tower controller may not have noticed the change of the status.

In Sheremetyevo airport the airfield (takeoff and landing) operations are interdependent. The controller shall continuously monitor the position of the arriving and departing aircraft. The investigation team examined the issue of the potential distribution of attention of the Tower controller at the point of the aircraft data block status change to the AFL1492 flight.

It was identified that at 15:25:59[196] the B738 aircraft to the NWS 524 flight landed on the RWY 24L. At that time the aircraft to the AFL1492 flight was flown at the distance of about 17 km off the RWY 24 L entry threshold.

At 15:26:34 the aircraft to the NWS 524 flight passed abeam the A5 TWY, at that did not vacate RWY 24L by the A5 TWY (as anticipated). Further on the aircraft initiated the RWY 24L vacation by the A4 TWY and the Tower controller visually monitored the runway vacation

[196] That is prior to receiving the RA-89098 aircraft for control.

process. At that point the aircraft to the AFL1492 was flown at the distance of about 15 km off the RWY 24L entry threshold.

At 15:26:58 the aircraft to the NWS 524 flight vacated RWY 24L by the A4 TWY, at that time the approaching aircraft to the AFL1492 flight was flown at the distance of about 13 km off the RWY 24L entry threshold.

Until the point RWY 24L became clear, the aircraft to the AFL1492 flight covered the distance from 17 km to 13 km off the runway entry threshold. The changes in the data blocks occurred at the point when the aircraft to the AFL1492 flight was flown at the distance of about 13 km off the RWY 24L entry threshold, and against the absence of the attracting sound alert, these changes could not have been noticed by the controller due to his checking the conditions of the upcoming landing.

Note: *As explained by the ATC officers, who assisted to the investigation team activities, the main method for the airspace situation monitoring at the aerodrome ATS is a visual monitoring on the part of the controller who directly exercises the ATC. The means for monitoring, such as the airfield surveillance radar screen, the Alpha ATC automated backup complex display, the TOPAZ ATM automated complex indicator, are auxiliary equipment and used by the controller depending on the stage of the aircraft flight and the necessity to obtain the required information. The indicator to the Topaz ATM automated complex is generally applied to get the information on the sequence of the arriving traffic, streamlined for approach adjacent to the aerodrome by the Moscow Air Hub ATC center. The Alpha ATC automated complex screen is used to clarify the routine information, as it is on this screen that the routine information boxes are displayed, as well as to measure the distance between the approaching aircraft. The data, obtained from the airfield surveillance radar screen, are applied to when the aircraft is flown on final approach.*

In the light of the stated in Section 2.7.1 of the Report and the fact that the crew, against the two-way radio communication with the controller, including after the 7700 squawk code setting, had not reported the onboard emergency, and the situation itself had not been the emergency, it has not been possible to impartially assess the actions by the Tower C2 sector controller with a view to their eventual effect on the outcome of the flight and severity of consequences. By contrast, in a general case, the fact that the Tower controller «had not noticed» over a long time the presence of the alert status in the data block to the aircraft, having been displayed on three different screens and had not reported it to the air operations supervisor, establishes the unacceptable risk to the aviation safety.

Later on the Tower controller relayed the current wind data to the crew and cleared landing to RWY 24L.

After the aircraft fire was detected by the ATS authority, the Center air operations supervisor, compliant to the Sheremetyevo International Airport, JSC Emergency Response Plan declared the Red code Alarm signal of the via the Gorn emergency alert system.

2.5. The analysis of the factors, affecting the survivability in the air accident

The AR-25 item 25.803 (c) «Emergency evacuation» stipulates*: For the airplanes with the passenger capacity of more than 44 seats it shall be demonstrated that the maximum number of people, for which the certificate is requested, included as many crewmembers, as required by the operational regulations, can be evacuated from the airplane to the ground within 90 sec. at the simulation of the emergency environment. The compliance to this requirement shall be shown by actual demonstration*[197]*, based on the criteria of the tests, set out in Appendix J to these Regulations, unless the competent Authority determines that the combination of analysis and tests will ensure the data, equivalent to these that may be obtained by the actual demonstration.*

According to the information, available to the investigation team, the compliance of the RRJ-95B aircraft type to the subject AR item had been shown by the actual demonstration, while obtaining the IAC AR and EASA type certificates[198].

The timeline of the emergency and rescue response conduct and the evacuation of the passengers and crewmembers is stated in Section 1.15.2 of the Report.

As evidenced by the survived flight attendants and passengers, before landing they had occupied the seats according to the issued boarding passes, only one passenger with the seat 3C boarding pass moved to the free 3A seat next to him on his own.

The last passenger (out of the survivors) had left the aircraft in 106 sec. after the start of the evacuation[199] (the opening of the right front door). At that this passenger had not sustain any significant injuries out of the effect of the fire factors.

The PIC had been the last to leave the airplane in 326 sec. after the start of the evacuation. At that he had been next to the front exits and had not used any protective equipment. The PIC had not sustained any significant injuries out of the effect of fire factors either.

Hence the actual time, within which some survivors had remained aboard the aircraft, had significantly exceeded the value, standardized for the evacuation. At that out of 73 passengers,

[197] At the demonstration the mentioned 90 sec. are counted from the point of the issue of the command for evacuation.
[198] While obtaining the FATA Type Certificate the demonstration in question had not been carried out.
[199] In this context it was not the point of the command issue by the flight crew that had been taken as the moment of the evacuation start by the investigation team, but the point of the first door opening, as the flight attendants made the decision to start the emergency evacuation on their own (see Section 2.6 of the Report as well).

having been on board, 40 people had been fatally injured (which is more than half), 1 crewmember had been killed as well (the flight attendant at the 2L exit). Taking into account that 14 seats in the passenger cabin had been unoccupied, the results of the accomplished emergency evacuation had been far worse than expected (those, having been demonstrated at the certification). Through this Section the possible causes of this had been subject to the analysis by the investigation team.

The makeup of the passengers

Among the passengers of the aircraft, women had accounted for 30%, persons over 50 years old – 16%, women over 50 years old – 3%, there had been two children as well, aged 11 and 12. There had been no people aboard the aircraft, who would have experienced difficulties in moving by their own (disabled passengers) or in perceiving the information. In compliance to the certification requirements, at the demonstration of the emergency evacuation the type normal healthy makeup of passengers constitutes: women – at least 40%, persons over 50 years old – at least 35%; women over 50 – at least 15%, in addition, there shall be three dummies on board, simulating children aged two years or less. That is to say, the actual makeup of the passengers had not been the factor, complicating the evacuation.

Illumination

The evacuation had been proceeded in daylight, that is, most probably, the actual illumination level had been at least this, set out by the certification requirements (3,2 lx). Hence, the illumination environment had not been the complicating factor to the evacuation.

Carry-on luggage

As evidenced by the survived passengers and cabin crewmembers, after the hard landing some overhead bins had been opened and the carry-on luggage had dropped out to the passenger cabin aisle. At that the statements do not contain any evidence that this had in any way complicated their evacuation from the aircraft. As per the certification requirements at the demonstration of the emergency evacuation *«about 50 % out of the total average number of the carry-on luggage, baggage items, blankets (plaids), pillows and other pieces of the kind shall be distributed in different areas into the aisles, these, adjacent to the emergency exits to establish small obstacles»*. The results of the dead bodies' examination do not contain any evidence that these passengers may have been injured as a consequence of the carry-on luggage dropout from the overhead bins. Thus the opening of some overhead bins and the carry-on luggage dropout to the passenger cabin aisle had not been the complicating factor to the evacuation.

Nevertheless, the statements by the survived passengers reveal that at the evacuation some of them had taken the carry-on luggage out of backpacks or small suitcases with them. The evacuation with the carry-on luggage is against the established procedures and had built «the jams» in the aisles. This is how the survived female passenger, having been allocated at seat 15C, describes what she had been observing: «*…On the way to the exit I saw (Post, Surname), who was getting his carry-on luggage out from the overhead bin, thereby he prevented other passengers from advancing to the exit. Apart from (Surname), there were other passengers, unknown to me, who also took out their carry-on luggage from the overhead bins, thereby they made an impassable jam in the aisle to the exit… Behind me there had been passengers as well who were as well trying to proceed to the exit. It was hard for all the passengers to breathe because of the heavy smoke that filled the cabin of the aircraft…*»

This female passenger had evacuated after the flight attendants had left the aircraft. After her, three more passengers had evacuated. The dead bodies of the several passengers out of the rear rows had been revealed lying in the aisle, at the area of 6-10 rows of seats, that is they had been advancing to the front exits. As per the results of the forensic medical examination of these fatally injured people (the carboxyhemoglobin in the amount of up to 62.5 % had been detected in blood) and the dynamics of the fire propagation, most probably, first, they had lost the ability to move against the body intoxication with combustion products, and death had occurred later due to exposure to high temperature factors.

In view of the above the difficulty in proceeding to the exit, associated with the carry-on luggage pickup by a number of passengers, could have affected the severity of consequences due to the prolongation of time of the allocation at the area of the organism exposure to the combustion products.

At that the CFA in her evidence notes that the carry-on luggage had not impeded the evacuation right at the exit to the escape slide.

The configuration of the emergency exits in use

It had been two front emergency exits only that had been used at the evacuation. It had been impossible to use the rear exits as they had been allocated in the fire seat. As per the certification requirements, at the demonstration of the emergency evacuation one of each pair of exits is used (as to the RRJ-95B the exits along the right side had been in use). Hence the actual situation – in terms of the possibility to use the emergency exits – went beyond the expected operational conditions. Taking into account that the vast majority of the fatally injured people had been seated close to the rear pair of exits, the impossibility of their use could have been the factor, adversely affecting the severity of consequences.

The panic and crush in the passenger cabin

As explained by the survived passengers out of the rear section of the aircraft (see Section 1.18.17 of the Report), after the third touchdown and the penetration of the smoke in the cabin the panic had broken out among the passengers. It follows from their evidence that the huge crush had been built up in the aisle because many passengers almost concurrently on their own (having not been commanded by the flight attendants) had unfastened the seatbelts and stood up. The situation had been worsened by the heavy smoke and the fact that some passengers had tried to pick up their carry-on luggage.

Heavy smoke in the rear passenger cabin, causing difficulty in breathing and burning in the eyes, had instinctively forced many passengers to move to the exit, having been bent low, and some of them having crawled along the aisle, which decreased the speed of movement.

The investigation team points out that it is impossible to predict in advance the passengers' behavior in the event of an unplanned evacuation, whether they will immediately stand up in the aisle or start acting by the commands of crewmembers.[200] In fact, the passengers acted and behaved, as having been forced by the rapid and extremely life-threatening situation and so far as their personal qualities permitted. Meanwhile, all the survived passengers from the rear rows had acted on their own initiative, without waiting for the commands by the flight or cabin crewmembers.

This way, the panic factor could have adversely affected the severity of consequences.

The early penetration of fire inside the passenger cabin

The death of the vast majority of fatally injured people in the air accident[201], having been occurred in a short period of time, had been caused by the extensive thermal injuries to the body out of the exposure to an open flame, accompanied by burns of the upper respiratory tract. The lifetime allocation of the fatally injured people in the fire environment is supported by the presence of soot in the respiratory tract, as well as the presence of carboxyhemoglobin in the blood. Section 1.16.17 of the Report outlines the probable causes of the rapid propagation of fire, one which had been the so-called «flashover» in the rear of the passenger cabin, where most of the dead bodies had been «compactly» located.

According to the information, submitted by NTSB in the course of the investigation, in April 1964 FAA had carried out the tests in situ aboard the Douglas DC7 aircraft to evaluate the post-accident fire effect on survivability. In September of the same year the similar tests had been carried out aboard the Lockheed L1649 airplane. At that time FAA had initiated the performance of the research, aimed at the prevention of two types of fire, erupting at the air accidents. It is just the flashover that had been one of the types. As indicated above this effect manifests, when the cabin furnishings (the fire load) is heated up to a certain temperature and instantly self-ignites over a large surface. At the tests in situ it had been determined, that the environment for the people' s survival in the undestroyed airplane fuselage in the external fire out of the jet fuel prevail for two minutes approximately, after which the heating of the passenger cabin becomes large enough for

[200] The analysis of the cabin crewmembers' actions is addressed in Section 2.6 of the Report.
[201] Except for one person, see Section 1.13 of the Report.

the onset of the flashover effect. It had been the indicated time span that had been taken as a maximum one to carry out the emergency evacuation.

The Amendment 121-2, issued on March 3, 1965 and titled «Regulations, Procedures, and Equipment for Passenger Emergency Evacuation; Flight Attendants; and Assignment of Emergency Evacuation Functions for Crew Members», suggested that the emergency evacuation should have been carried out in two minutes maximum with the use of only half of the present exits. By the same amendment the mandatory preflight safety briefing on the emergency evacuation procedure had been introduced. Further on, at the advancement of technologies, ensuring the emergency evacuation, including the mandatory equipment with the escape slides, the maximum time had been shortened down to 90 sec.

On the assumption that the fire had penetrated in the aircraft rear section on 15:30:54 at the latest (i.e. no later than in 8 sec. maximum after the opening of the first door to evacuate), the indicated 90 sec. had not been available to the passengers, allocated in the rear passenger cabin.

The fast penetration of the open flame in the passenger cabin, which is mentioned by the 18A seat passenger in his statement (see Section 1.18.17 of the Report), is confirmed by the presence of the burn injuries to the survived female passengers, having been allocated in seats 12D and 15C. The clinical diagnoses respectively are: *«Serious inhalation injury. The third degree burn of the respiratory tract. The first-second-third degree flame burn of 15 % of body: face, back, arms. The first degree burn of conjunctiva»* and *«The first-second degree flame burn of face, torso, upper limbs of 15 % of body. The second degree thermo-inhalation injury. The first degree burn of eyes. The poisoning with the combustion products»*. Those women, the only survived passengers, had sustained the burn injuries to the body, having been allocated in the passenger cabin.

As stated in Section 1.16.18 of the Report, most probably, the fire had been propagated inside the passenger cabin through several cabin windows at once along the left and right side at the area of FR40-46. At that according to Saint-Gobain Sully company (France), the manufacturer of the cabin windows, the cabin windows engineering specifications and certification requirements[202] do not provide the criterion to withstand the external fire (the burning jet fuel), especially with the running engines, creating the effect of «the gas burner».

Hence, most probably the significant number of the fatally injured people in the rear passenger cabin is due to the factors as follows:

- the impossibility to evacuate through the rear exits;
- the crush, built up in the passenger cabin (especially in the rear section) because of

[202] This statement is true not only for the RRJ-95B type, but for all the other modern aircraft types (see Section 1.18.24 of the Report as well).

the ensued panic and the efforts of the number of passengers to pick up their carry-on luggage;

- the fast penetration of smoke and fire (through a row of cabin windows) in the rear passenger cabin with the possible manifestation of the flashover effect.

Generally the investigation team concludes that the conditions, in which the emergency evacuation had been proceeded, were fundamentally different of these, under which the compliance demonstration had been carried out, that is went beyond the expected operational conditions. At the recurrence of the circumstances of the air accident under consideration, critical from the point of view of the early penetration of fire in the passenger cabin, the likelihood of death of the passengers and cabin crewmembers is high.

2.6. The analysis of the cabin crew's actions

In compliance to Aeroflot, PJSC SMM (Part 1 item 12.1), the operator shall establish the sufficient, from the point of view of the State of the Operator, minimum number of the cabin crewmembers for each type of airplane, based on the passenger capacity or the number of the transported passengers, in order to ensure the safe and rapid evacuation of people, as well as the performance of the necessary functions in an emergency or in a situation that requires the emergency evacuation. The operator is to define these functions for each aircraft type.

According to the RRJ-95 FCOM, minimum cabin crew is 2 people. As per the Aeroflot, PJSC OM, the RRJ-95 aircraft minimum cabin crew had been extended up to 3 people. Thus, the number of the cabin crewmembers had met the established requirements and had not anyhow affected the severity of the air accident consequences.

All the cabin crewmembers held the valid air personnel licenses with the authorization for the aircraft type and the medical certificates. As per their health status they had been authorized to perform the flight.

Still, as noted in Section 1.5.2 two out of three flight attendants had undergone their last qualification check aboard the RRJ-95 aircraft more than a year ago[203]. As per the airline OM Part A item 5.6.7, the recurrence of the checks performance to confirm the qualification of the Russian Federation civil aviation flight attendant in line flight is at least annually. With that the OM does not contain the information whether these checks shall be carried out on each type of aircraft, for which a specialist holds the authorization. The Federal Aviation Regulations do not determine the recurrence and procedure for the qualification check of the flight attendant license holder. The investigation team is of the view that as the allocation of emergency and rescue equipment and the order of the cabin crewmembers' actions in an emergency are typically different as for the different

[203] Less than a year ago the qualification check had been arranged aboard the other aircraft type.

aircraft types, it is expedient to arrange the check aboard each type of aircraft. As discussed below, the CFA, while ensuring the emergency evacuation had made a mistake in operating the communication equipment.

As for the RRJ-95 aircraft in case the cabin crew is composed of three people, they should be allocated at the 1L, 1R, 2L duty stations. As far as the flight that ended with the accident is concerned 2 flight attendants had been allocated in the front compartment at the 1L and 1R doors (including the chief one), one flight attendant had been stationed in the rear compartment at the 2L and 2R doors. In this way the actual allocation of the flight attendants had been in line with the SMM provisions.

By contrast the youngest and the least experienced flight attendant had been allocated alone in the rear aircraft section. In addition he had not performed any flights over at least 30 previous days. The investigation team points out that in terms of the risk monitoring it would have made more sense to allocate this flight attendant together with the CFA. According to SMM, the Flight Safety Department may have made this kind of decision. Actually then, the cabin crew CRM by the CFA had not been the best possible.

Note: *According to the Aeroflot, PJSC SMM the distribution of responsibilities in the cabin crew is carried out to optimally arrange the cabin crew working activities… The Flight Safety department is entitled to shift the duties in the cabin crew, promptly responding to the specific flight environment … (Part 1 Chapter 14 item 14.9.5 and 12.1).*

As witnessed by the cabin crewmembers, having been allocated on the seats next to the 1L and 1R doors, in the progress of descent for landing the passengers had been occupying their seats with the seatbelts fastened. The flight attendants were allocated at their staff seats (duty stations) with their harnesses and belts fastened. There was no information, communicated by the crew to prepare passengers for emergency landing.

The passenger evacuation out of the aircraft had been «unplanned» (see item 3.10 of ICAO Cir 300 AN/173 «Human Factors Digest No. 15. Human Factors in Cabin Safety»). Only the flight attendant at the 1R exit had noted at the interview that «by intuition» she had been getting ready for the emergency landing.

After hard touchdowns with several bounces off the RWY, into the landing roll, the flight attendants by the 1L and 1R exits and (as explained by them) through the cabin windows had seen the fire outside at the area of the fuselage tail section. At 15:30:30 the CVR recorded the information (the report) of the CFA to the flight crew: *«Fire on board»*

After the aircraft stopped (at 15:30:38) the flight attendant by the 1R door without the command unfastened the seatbelt and started to open the door. The door was opened at 15:30:46.

Note: ***As per the record of interview of the flight attendant by the 1R door of May 28, 2019***

I was waiting for the complete stop to start the evacuation. After the aircraft stopped, I told [full name of the CFA] that there was a fire outside along her aircraft side. Inside the cabin white thin smoke began to appear. I unfastened myself and without waiting for the command rushed to the door. The door was opening slowly and I started pushing the door with my hand and then with the foot. After the door opened, the smoke started to fill the cabin even harder, maybe because of the incoming air out from my opened door.

Hereby, the emergency evacuation had been started by the cabin crew on their own, without the command by the flight crew. The investigation team notes that generally the evacuation shall be started by the command of the flight crew. This is due to the fact that before starting the evacuation to ensure it the flight crew should do a number of actions (see Section 1.18.9 of the Report), including shutting the engines down.

At that the RRJ-95 QRH (Section 1.18.10) allows for initiating the evacuation by the flight attendants on their own (without the command by the flight crew) if it is definitely known that it will be required and there is no communication with the flight crew. As evidenced by the cabin crew, the smoke appeared inside the cabin after the aircraft stop and through the cabin windows the fire was seen outside, that is to say there was no doubt that the emergency evacuation must be started. There was no information by the flight crew on the landing. The investigation team is of the opinion that the cabin crew's decision to start the evacuation without waiting for the flight crew's command had been intelligent, consistent with the established situation and had not been against the Aeroflot, PJSC Flight Attendant Manual provisions.

Note: *At the post-accident interview of the flight and cabin crewmembers they had been observing difficulties in maintaining the intercom communication after the aircraft encountered the atmospheric electricity, i.e. into the descent and approach. Meanwhile the investigation team had not revealed any signs of the failures to the equipment in question as per the flight data recorders. As stated in Section 1.18.25, the non-delivery of a number of utterances from the PIC to the CFA, most probably had been due to non-pressing of the PTT pushbutton by the PIC at proceeding the radio contact.*

The video footage shows that at the point of the door opening the light smoke, coming out of the aircraft, appeared at its upper part. It can be concluded that the smoke was propagating along the passenger cabin ceiling, which is confirmed with the statements by the cabin crew and passengers (see Section 1.18.17 of the Report).

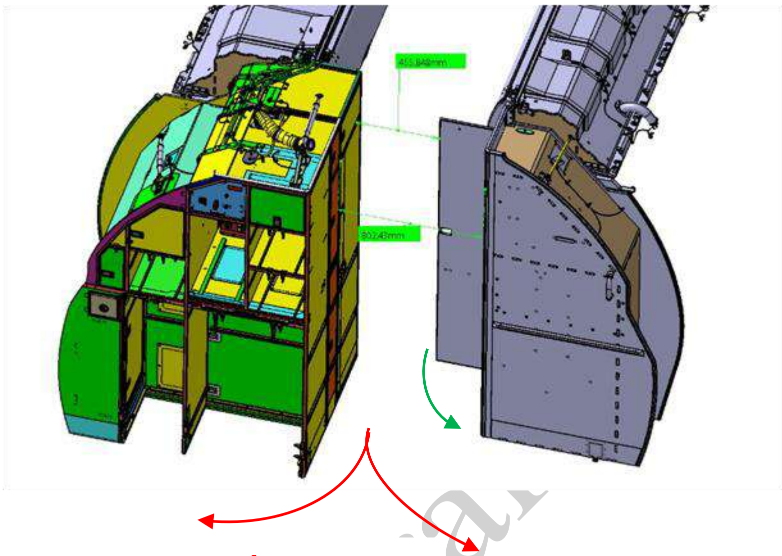
At 15:30:49 the CVR captured the command by the CFA *«Seat belts off, leave everything, get out! »*. This command is in line with the standard phraseology. The command was given distinctly and loudly in two languages (Russian and English) with the pronounced command intonation. The CFA after the accident stated that she had given this command to the cabin via the public address system, but it (the public address system) had not functioned. By contrast, as per the information, stated in Section1.18.25, it had been the flight crew cockpit that this command had been given to, but not in the passenger cabin. Most probably, having been in stress the CFA made an error in operating the communication equipment.

Note: *The investigation team points out as well that «generally» as for the RRJ-95 aircraft the public address communication is not to function in the progress of the passenger evacuation due to the complete aircraft power off by this point of time as the outcome of the SOP, done by the flight crew (see Section 1.18.9 of the Report). At that the similar procedures by the other aircraft designers (Airbus and Boeing, for instance, see Section 1.18.30 of the Report), at their virtually full identity as for the other procedures, do not integrate the item on the requirement to power off the aircraft.*

The AR-25 item 25.1423 requires the public address system be supplied with power in flight or at the aircraft stand on ground within the time of 10 min. at least, including the time of total duration of at least 5 min., required for the flight crew and flight attendants' announcements, after the shutdown or failure to all the engines and APUs, or the disconnection or failure to all the power sources, taking into account all the other loads that may be supplied by this source at all the remaining power sources, being inoperative. As per the data available, from the technical point of view (by design), the RRJ-95 aircraft meets the subject requirements.

As evidenced by most survived passengers they had noted that either had not heard the command on the start of the evacuation, or had not been able to give a straight answer. Only 7 passengers had heard the command. No command over the public address system is also supported by the analysis of the sound tracks to the available video footages by the cell phones out of the aircraft passenger cabin. This fact could have complicated the spatial awareness of the passengers, especially those who had been allocated in the middle and rear sections of the passenger cabin, and affect the evacuation speed and the severity of the air accident consequences.

The investigation team points out that at the issuing of the commands the flight attendants had not used megaphones (see Section 1.18.11 of the Report as well). After the air accident the megaphones had been discovered at their assigned location. At the interview the flight attendants did not communicate that they had attempted to take the megaphone out. The CFA mentioned that the effort to open the closet door (where, among other things, the megaphone is located) could have obstructed the way to evacuate. Still the investigation team notes that the closet door, when opened, does not completely block the way from the passenger cabin to the front compartment and is designed in such a way that the direction of its closing matches the direction of the passengers' movement to the emergency exits (Fig. 188).



Direction to the exits

Fig. 188. The closet door in the front compartment

By contrast, the flight attendants' access to the megaphone can be complicated at the unplanned emergency landing, on condition that passengers start moving to the emergency exits before the issuance of the command by a flight attendant. Under the impossibility to predict in advance the passengers' behavior in the event of an unplanned evacuation (whether they will immediately stand up in the aisle or start acting by the commands of crewmembers) it is reasonable to enable the flight attendant to take the megaphone out and use it to give the commands regardless of the circumstances in question. In such a case the availability of the voice communication with the flight attendant in the rear compartment will be retained as well.

It is worth mentioning that the AR-25 item 25.1423 «The passenger public address system» sets out the requirements to the fixed public announcement appliances, including in terms of their accessibility to the flight attendants (the 25.1423 item part g). As far as the megaphones are concerned, there is one requirement only on the reliability of their securing at the exposure to the inertia forces (the AR-25 item 25.1421). The investigation team considers it expedient to address the issue of the megaphones allocation in a manner (with the introduction of amendments in the certification requirements to transport airplanes), that they can be accessed with no actions, complicating the evacuation.

The 1L door had been opened by the CFA. The door had been opened at 15:30:55.

Note: ***As per the record of interview of the flight attendant by the 1L door (the CFA) of May 28, 2019***

After the complete stop I issued the first block of commands via the public address system, but it malfunctioned. After that I started to open the front left door and held the passengers still till the escape slide was fully inflated. The thick black smoke started to penetrate through the opened door. I stepped back closer to the cockpit and proceeded with the passengers' evacuation.

At the spillage and burning of fuel the passenger evacuation might have been proceeded with the use of only the half of the available exits – through the 1L and 1R doors. The flight attendant, allocated in the rear compartment, had not to open the 2R and 2L emergency exits, as there had been an intense open fire outside them. He should have guarded those exits, preventing them from use and command the passengers' direction to the front section of the passenger cabin (see Section 1.18.11 of the Report).

The view from the flight attendant's duty station by the 2L door at the absence of factors, degrading the visibility, is sufficient to visually monitor the passenger cabin (Fig. 189 and Fig. 190).

Fig. 189. The view from the seat of the flight attendant, sitting straight at the duty station

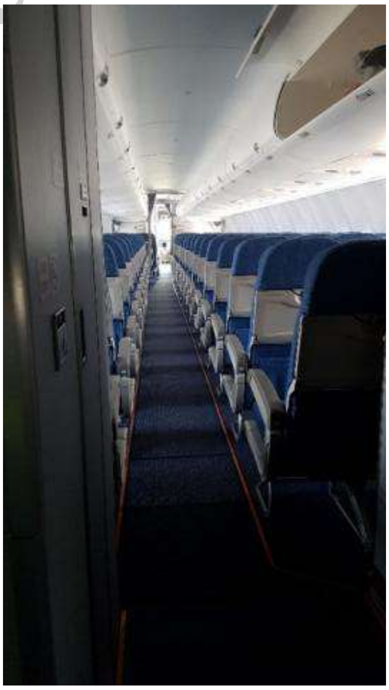


Fig. 190. The view from the seat of the flight attendant, leaning to the right

The survived passengers' explanations do not allow concluding on what had happened in the passenger cabin behind the 11-12 rows of seats. According to the survived passengers and flight attendants after the aircraft stopped the passengers began to stand up from their seats, there were screams heard: *«We are on fire! »* and *«Fire! »*. At the rear passenger cabin the heavy smoke began to propagate and the fire appeared. It can be assumed that in degraded visibility due to smoke, at the breakout of panic and the crush in the aisle the flight attendant at the rear compartment had no information on the environment in the front aircraft section, including the availability of the front emergency exits to evacuate.

The flight attendant, allocated at the rear compartment had been fatally injured and found outside of the aircraft next to the 2L door. He had been the only fatally injured person, found outside the aircraft. The 2L cabin door had been destroyed exposed to the significant thermal effect, the door support arm had been observed in the open position. With high probability this indicates that it had been the flight attendant, whom the door had been opened by. At that the signs are detected of the door opening from the MANUAL position, without actuating the escape slide (the escape slide bar had not been attached to the floor and located outside the aircraft).

The door opening at the fire outside is unacceptable. The SOP (see Section 1.18.10 of the Report) explicitly require that before opening the door the flight attendants make sure by the door window that there is no fire outside. The reasons, on which these erroneous actions had been taken cannot be clearly determined. A relatively little working experience of this flight attendant could have been the probable reason, which at his allocation in the rear passenger cabin against no communication available with the other cabin crewmembers, heavy smoke in the cabin and panic among the passengers might have resulted in the error in question. As the carboxyhemoglobin had been detected in the flight attendant's blood, the exposure to the adverse effect of the poisoning with carbon monoxide cannot be ruled out.

There is no way to explicitly determine the time of the left rear door opening. It can be asserted that it had occurred not earlier than at 15:30:58 (see Section 1.15.2 of the Report for details), when the fire definitely penetrated inside the fuselage. As per the fire propagation simulation (see Section 1.16.18 of the Report), the discussed erroneous flight attendant’s action to having opened the door in this particular case could not have significantly affected the magnitude of the fire destructive effects on the fire propagation and thereby the severity of consequences.

The cabin crew had evacuated the total of 29 passengers out of the airplane. As evidenced by the CFA the evacuation had been proceeded up to the point of the front compartment entire surface filling with the thick black smoke, because of which the passenger cabin area had not been visible. The black smoke out of the passenger cabin had been rapidly penetrating the front compartment, which, in her assessment, had begun to threaten the life of the cabin crew. Commanded by the CFA at 15:31:28 the flight attendant by the 1R door evacuated the first by the 1R door escape slide. The CFA after the inspection of the accessible portion of the cabin left the airplane at 15:31:39 by the 1R door as well.

Note: *As per the RRJ-95 CCOM item 10.30 «After the evacuation of the passengers»: «…If there are no passengers in the assigned area or if it is no longer safe to stay aboard the aircraft, the cabin crewmembers shall evacuate through any nearest accessible emergency exit».*

After the flight attendants left the airplane, assisted by the flight crewmembers, remaining on board and one of the airplane passengers 4 more passengers (including this, who assisted to the evacuation) evacuated through the 1R door. The last survived passenger left the airplane by the 1R door at 15:32:32, that is in approximately a minute after the flight attendants evacuated. The PIC had remained on board in the front compartment up to 15:36:12. In view of the stated, the investigation team finds it difficult to clearly assess the reasonableness of the flight attendants' leaving the aircraft at the time, specified above.

The application of the aircraft emergency and rescue and portable firefighting equipment

The aircraft had been equipped with the cabin crew smoke hoods/PBE and hand fire extinguishers. This equipment is as assigned intended to extinguish the small local fires in-flight. The design of the PBE allows only the respiratory organs to be protected from suffocation, but does not protect the body (except for the head), being exposed to fire and high temperature.

The application of the PBE by the flight attendants implies the following actions: to open the closet, to remove the container protective cap, to get the PBE out of the container, to uncover (break off) the package and get the PBE out, to straighten the PBE and put it on over the head, to actuate the oxygen generator. The total required time to complete these actions is 30-60 sec. At getting the PBE out the opened closet door partially blocks the way to the emergency exits. The PBE structure (the speech diaphragm) impedes the loud and clear command issuance. In view of the above, as the main task at the emergency evacuation (including at fire) is leaving the aircraft in the shortest time (90 sec. at most), the SOP do not provide for the application of the PBE by the flight attendants straight at the emergency evacuation.

Nevertheless, as noted above, after the flight attendants leave the aircraft four more passengers had been evacuated and the PIC had stayed at the front compartment 220 sec. more after the last passenger left the aircraft. As indicated in Section 1.13 of the Report the significant number of the fatally injured people had been discovered on the border between business and economy class, at that, most probably, first they had lost the ability to move against the organism intoxication with the combustion products, and the death occurred later due to the exposure to the high temperature factors. As there is no accurate information on the time of the fire propagation into the mentioned area, the investigation team cannot clearly assess the potential of the application of the PBE by the flight attendants and the rescue of more passengers. Still the relatively long stay of the PIC aboard the airplane without any protective equipment allows assuming that there had been the option of the kind. Likewise as per the explanatory note by the passenger, who had assisted the flight crewmembers after the flight attendants evacuated, he suggested that this equipment should have been used, but the crew had not made this decision.

On July 9, 2006 the air accident occurred to the A310 F-OGYP aircraft at Irkutsk aerodrome. At the landing roll after touchdown, the airplane had run out of the entire runway length with the subsequent excursion. At the distance of ~ 300 m off the runway end threshold there occurred the aircraft impact of the aerodrome concrete fence and the garages, located out of the aerodrome territory in the immediate area. As the outcome of the air accident the fire had erupted at the airplane. 125 out of 203 aircraft occupants had been killed, whereby 124 of them had been fatally injured of the carbon monoxide poisoning.

The conclusions by the investigation team to the investigation of the air accident in question read: *«The existing smoke protection equipment is designed for the in-flight fire extinguishing. The procedure and the necessity of its application at the emergency evacuation are not determined. The respective cabin crew drills are not provided for».*

The investigation resulted in the issuance of the safety recommendation, addressed to EASA[204] and the other certification authorities, as follows: *«consider practicability of the existing smoke protection means use by the flight attendants at the emergency evacuation; consider the possibility of equipping large transport aircraft with the specific devices, protecting passengers and cabin crewmembers from smoke and toxic gases at the emergency evacuation».*

At the obtained EASA response the first part of the safety recommendation in question is not supported. To substantiate its stand EASA had come up with the arguments, associated with the initial purpose to PBE, which are stated here above through the text of the Section. The investigation team agrees with the mentioned arguments in terms of the active process of the emergency evacuation notably. By contrast as both in case of A310 aircraft and the occurrence under consideration the investigation team reasonably believes that the application of these devices on the completion of the active stage of evacuation to assist these passengers, who lost the ability to move out of poisoning by the combustion products, could have decreased the severity of the air accident consequences.

The second part of the safety recommendation had not been supported either. In its response EASA points out that the issue of the passenger cabin equipment with the means, designed to decrease the adverse effect of the combustion products, had been repeatedly raised. The respective research had been carried out, which resulted even in the development of the appropriate standard to this type of equipment and the allotted samples had been subject to tests.

[204] As to the authority, having issued the A310 aircraft original Type Certificate.

It had been determined that the means of the kind could be implemented, however it is difficult to arrange the cost-benefit assessment. Finally it had been recognized more practicable to enhance the ultimate aircraft resistance to the destructive factors of fire and improve the potential of evacuation.

The investigation team points out that one of the arguments that had been come up with against the implementation of the devices in question was that it is impossible to guarantee appropriate use of these devices by the passengers, even against the associated preflight information briefings. By contrast some survived passengers had noted at their explanatory notes that they had instinctively used means at hand (the clothing items, etc.) to protect the respiratory system into the advancement to the emergency exits and expected the oxygen masks to drop down as well.

Based on the stated the investigation team finds it expedient that the certification authorities and aircraft manufacturers revert to this issue.

The condition and application of the aircraft emergency and rescue equipment

All the portable emergency and rescue and oxygen equipment (except for the oxygen cylinders, located in the destructed rear baggage compartment along the right side, and two flight crewmembers' flashlights[205]) had been retrieved at the assigned locations.

The escape slides – the front left and right ones – had deployed at the doors opening and inflated at the operating position as assigned. The rear left escape slide had not inflated at the operating position as the door had been opened out of the MANUAL position.

The F/O had used the escape rope to leave his duty station through the right cockpit window.

2.7. The analysis of the emergency and rescue teams' actions

The air accident had occurred within the aerodrome area and had not required the performance of search. Through this section the emergency and rescue teams' actions are subject to analysis.

The air operations emergency and rescue support at Sheremetyevo airport was carried out in compliance to USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 and «The Guidelines on the firefighting methods and tactics to aircraft at the civil aerodromes», approved by the USSR Ministry of Civil Aviation by the Instruction # 21/и of December 11, 1990, as well as compliant to the Sheremetyevo International Airport, JSC Emergency Response Plan (ПЛ-2.3-02-15), approved by the Sheremetyevo International Airport, JSC Order # 267 of May 25, 2016 and «The operational plan on firefighting to the aircraft at

[205] These had been used by the flight crew at the emergency evacuation.

Sheremetyevo International Airport», approved by the Sheremetyevo International Airport, JSC operations general manager first deputy Order of May 24, 2016.

At Sheremetyevo aerodrome the required fire protection level of the ninth category is determined to each runway (the standard quantity of the aerodrome vehicles on standby is five). Taking into account the data on the number and performance of the firefighting vehicles, stated in Section 1.15.1 of the Report, the established required fire protection level complied with the requirements of the USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 Appendix 13 item 2, including: the number of the firefighting vehicles (6 aerodrome vehicles, it shall be at least 5)[206], the total quantity of the fire suppressants (62100 kg, it shall be at least 41000 kg), including the foam agent (5900 kg, it shall be at least 2870 kg). The total aerodrome firefighting vehicle output at the fire suppressant discharge via the roof fire barrels[207] had amounted to 310 kg/sec. (it shall be at least 226 kg/sec.).

As for the RRJ-95B aircraft, its fuselage length is 29.9 m, the width is 3.4 m, which, according to the USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 Appendix 13 Table 1 attributes this airplane to the required fire protection level of the sixth category (the required number of the aerodrome firefighting vehicles is 3).

The Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service had undergone the required training and had the necessary experience to ensure the emergency and rescue response.

The training of the fire rescue crew personnel to the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service had been carried out, compliant to established and approved annual plan of the time distribution by disciplines and months of training. The fire rescue crew personnel had been trained at the training ground on the methods and tactics of extinguishing the different fire types to the aircraft, where every fire rescue crew undergoes the practical training at least twice a month.

To practice the actions in the event of different sorts of emergencies at Sheremetyevo International Airport, JSC «The drill plan to the Sheremetyevo International Airport, JSC personnel, handling operators and interacting authorities on the actions at the onset and elimination of the abnormal, failure and emergency situations of the year 2019» had been developed.

Over a year all the fire types are subject to drill (this out of the spilled jet fuel, the fire inside the fuselage, the fire to the landing system and powerplant) together with the simulation of the combination of the concurrently erupted aircraft fires. This way, over March 18 – 21, 2019

[206] The requirements had been met even with no account for the Strela-8 aerodrome firefighting vehicle, which at the point of the air accident had been at the Runway Emergency and Rescue Station-2, subject then to the water replenishment upon the completion of the drill.
[207] It is these, by which the fire had been actually extinguished.

between 22:00 - 01:00 (01:00 - 04:00 local time), a special night drill had been held to practice the actions and procedures by the Red code of the Sheremetyevo International Airport, JSC Emergency Response Plan by the personnel to the Sheremetyevo International Airport emergency and rescue teams, handling operators and interacting authorities. Into the drill, in particular, the tasks of extinguishing the fire out of the spilled fuel (setting fire to pans with a combustible mixture; the use of the smoke bombs, the smoke in the cabin) and the rescue of passengers (with the use of dummies) had been drilled at the Il-96-300 aircraft-simulator.

The investigation team points out that this drill scenario to a certain extent had been consistent with the emergency, having occurred on May 5, 2019. Meanwhile the actual environment had been more complicated due to the rapid penetration of the open fire in the aircraft cabin.

The timeline of the emergency and rescue operations is addressed in Section 1.15.2 of the Report.

The emergency had been first announced at 15:30:18, the air operations supervisor declared the Alarm signal at 15:30:58. The first firefighting vehicle arrival at the site of the aircraft stop and the start of the fire extinguishment occurred not later than at 15:32:07, the fifth and sixth aerodrome firefighting vehicles arrived not later than at 15:33:52. As required by the USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 item 3.27, if the accident site is located within the thresholds to each runway, the standard time of the first aerodrome firefighting vehicle arrival out of the number, compliant to the required fire protection level established category shall not exceed 3 min. from the point the Alarm signal is declared, as for the next vehicles to arrive it shall be 4 minutes. It had been 1 min. 9 sec. from the point of the first aerodrome firefighting vehicle arrival, as for the fifth and sixth aerodrome firefighting vehicles it had been of 2 min. 54 sec. Hence, the established standards of the arrival to the accident scene and the start of the emergency and rescue response had been met.

Note: *The USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 Appendix 13 item 3:*

«Anywhere at each artificial RWY the time of deployment of the first aerodrome firefighting vehicle (out of the number, established by the relevant category) shall not exceed 3 minutes, for the next vehicles to arrive – 4 minutes from the point the Alarm signal is declared to the fire rescue crews».

The aircraft stopped with the magnetic heading 115°, at that the wind direction was 160° (heading the right side of the aircraft). As explained by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service fire and rescue division sector crew leader (he arrived in the Strela-8 aerodrome firefighting vehicle), on arrival at the accident scene, the left side of the fuselage was heavily smoked due to the direction of wind from the right side.

After the aircraft stopped, the intensive fuel leakage with spillage was proceeded out of the disintegrated fuel tanks. The CCTV records data are the evidence that by the time of the arrival of the first aerodrome firefighting vehicle, the wing and the segment of the aircraft airframe were consumed by fire in between the compartment # 3 (FR24) and the fin (the vertical and horizontal empennage were not visible in flames and smoke), the aircraft engines had been already shut down.

The members to the emergency and rescue team confirm the intense fire of the aircraft. At the Strela-8 aerodrome firefighting vehicle arrival the burnout was observed in the upper fuselage, out of which the flame burst out. As the Strela-6 firefighting vehicle arrived at the accident site its crewmembers noticed the fuselage burnout *«right up to the frames», «the flame burst out of the fuselage burnouts», «the burnouts in the fuselage could have been seen, out of which the flames burst out as well»*. The drivers to the Strela-3, Strela-6, Strela-11, Strela-5 firefighting vehicles described the aircraft damage in a similar way. As explained by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service fire and rescue division sector crew leader, having been in the Strela-9 aerodrome firefighting vehicle, by the point of arrival *«the fire was inside the fuselage»*.

In line with the requirements of the USSR Civil Aviation Air Operations Search and Emergency and Rescue Support Manual-91 item 3.29.3, the fire shall be extinguished, compliant to «The Guidelines on the firefighting methods and tactics to aircraft at the civil aerodromes». According to this document the search and rescue response shall include:

– the arrangement of fire ground reconnaissance. The reconnaissance is to start as early as while the firefighting vehicle is proceeding to the accident site. At that, the following fire properties are to be evaluated: the number of combustion sources, the surface of burning, the allocation of the combustion sources against the aircraft fuselage (one-sided or two-sided fire), the direction of the fire propagation, the presence of fuel, leaking into the source, the threats to the fuselage survivability, especially at the areas, adjacent to cabins and cockpit, as well as the other factors, complicating the fire extinguishing. Besides, it is required to evaluate the direction of the wind and the way it affects the fire development;

– the deployment of the firefighting vehicles. The deployment comprises the set-up of the fire suppressant discharge means, which is to start as early as while the firefighting vehicle is proceeding to the accident site in such a way that on arrival to the aircraft on fire to immediately discharge the fire suppressant to the fire seat, as well as the allocation of the firefighting vehicles on the combat positions, the laying of the hose lines, when required;

– the fire extinguishing. The main goal at the extinguishing of the jet fuel, spilled under the aircraft, is the suppression of the external fire in minimum time, primarily at the areas, adjacent to cabins and cockpit, as well as the establishment of the escape route out of the aircraft. The extinguishing shall be accompanied with the cooling of the aircraft.

According to the reports by the crews to the aerodrome firefighting vehicles, at the proceeding to the aircraft the fire reconnaissance was carried out: the fire had been attributed as a two-sided one (over the entire surface); the threat had been determined, associated with the fuel spillage and burning under the aircraft.

By the point of deployment the fire rescue crews had not have yet the data of the number of people, having been subject to evacuation, and the total number of people on board. The opened doors in the front fuselage and deployed escape slides indicated the evacuation was going on.

The Strela-1, Strela-3 and Strela-5 firefighting vehicles, the three ones to arrive first, took up the combat position and started to suppress the fire seat, having allocated at the right rear against the aircraft wing (Fig. 191), discharging the fire suppressant to the area, adjacent to the fuselage compartment # 4, and this of the spilled fuel.

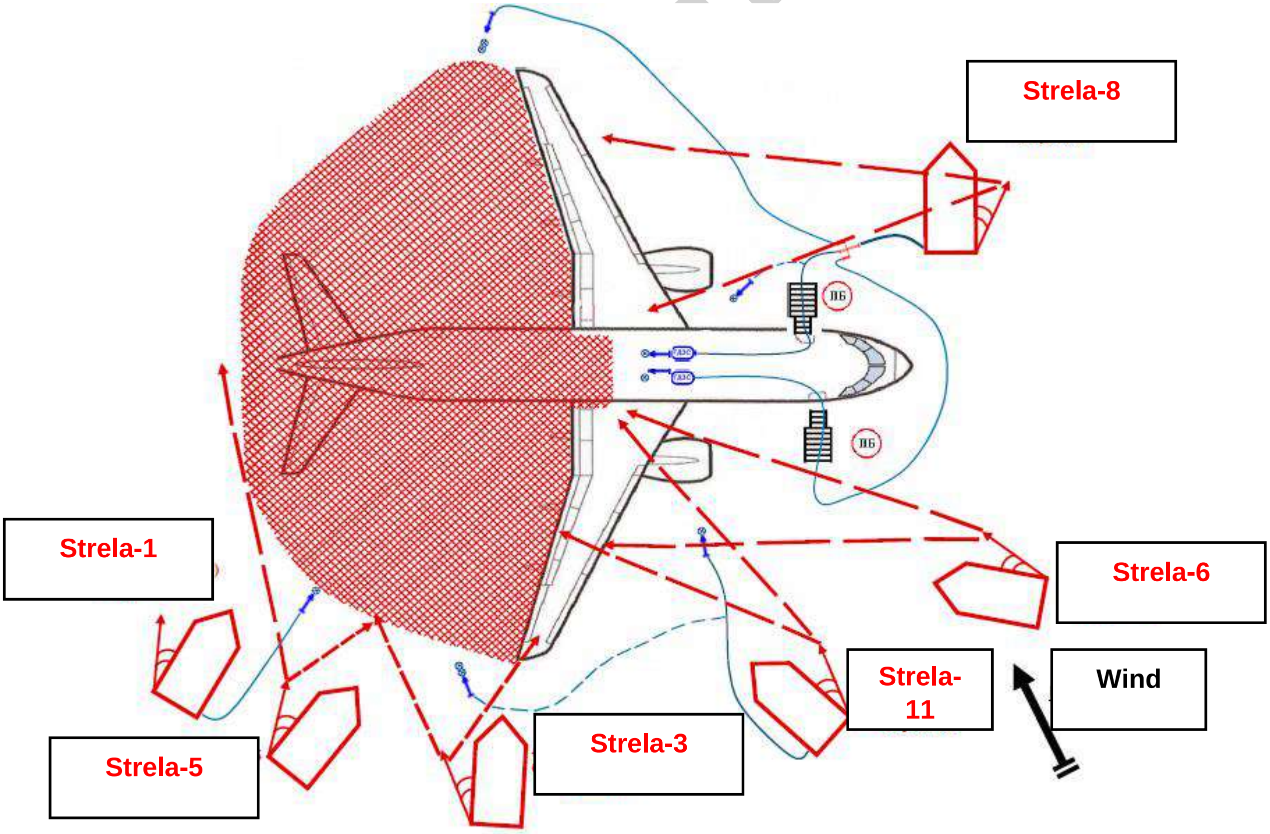


Fig. 191. The layout of the workforce and means at the fire extinguishing (the red lines stand for roof monitors, the blue ones do for the hose lines)

Strela-11 and Strela-6, which arrived next, took up a combat position to the right in front, whereas Strela-8 did to the left in front against the aircraft wing, which enabled the isolation of the flame off the front part of the fuselage that was not in fire (compartments # 1, 2 and 3), thereby establishing the possibility of using the front entry and front service doors.

The firefighting vehicles allocation was in line with the guidelines of «The operational plan on firefighting to the aircraft at Sheremetyevo International Airport (ПЛ-3.5-02-16) ».

The fire was extinguished by the foam attack out of fire monitors.

In the progress of the fire extinguishing five hose lines out of three firefighting vehicles (Strela-1, Strela-11 and Strela-8) were deployed with the fire suppressant discharge by the hand branch pipes: 4 РСКУ-50 hand branch multipurpose pipes and 1 Purga pipe.

After the fire suppressant was depleted, the team leader instructed the firefighting vehicles to proceed for replenishment with water to the nearest fire hydrant and the Air Operations Search Emergency and Rescue Support Service warehouse (located at the Base Emergency and Rescue Station) to be filled/refilled with the foam agent.

The fire was isolated at 15:41:43 and suppressed at 15:48.

Thus, the crucial way of extinguishing the fire had been selected right by the Air Operations Search Emergency and Rescue Support Service fire rescue crews, which enabled the use of the front fuselage exits. The fire rescue crews response at the fire suppression had been generally consistent with the actual environment on the air accident scene and in line with the provisions of Section 4 to The guidelines on extinguishing fires to aircraft at the civil aviation aerodromes.

At that the investigation team points out that the comparison of the maximum time limits to arrange the emergency evacuation out of the aircraft (90 sec.) and the arrival of the first aerodrome firefighting vehicle (180 sec.), even taking into account that the aerodrome firefighting vehicle departure may occur earlier than the start of the evacuation, allows concluding that in substantial number of cases the evacuation should be already completed by the time of the aerodrome firefighting vehicle arrival. Hence the potential of the emergency and rescue teams to assist the evacuation of survivors and thereby decrease the severity of consequences of the air accident is significantly limited.

In the event under discussion by the point of the first aerodrome firefighting vehicle arrival the majority of the survived passengers (29 people) and two cabin crewmembers had already evacuated out of the aircraft, the last survived passenger left the aircraft when two vehicles had already initiated the fire suppression on the air accident scene.

Note: *The statements by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service employees, having been involved in the fire extinguishing, read that by the point of their arrival to the aircraft «the evacuation had been completed». This* *conclusion had been most probably based on the fact that the active stage of the evacuation, into which 29 people had left the aircraft, had been completed when the fire rescue crews had not yet arrived to the accident scene.*

The actions by the Gas and Smoke Protection Service

The fire had been a two-sided one (on the both sides of the fuselage compartments # 4, 5 and 6) that had not enabled the fire rescue crews approach to the 2L rear entry and/or 2R rear service doors. This way, it had been possible to get into the airplane by the 1R and 1L doors only.

The first attempt by the firefighters to get into the airplane by the 1R door had been recorded at 15:32:53, however, the firefighter had been unable to climb the escape slide.

At 15:35:44, after the fire escape ladder had been installed by the 1R exit, At 15:35:44 the rescuer of the first squad to the Gas and Smoke Protection Service got inside the aircraft.

As evidenced by the Sheremetyevo International Airport, JSC Air Operations Search Emergency and Rescue Support Service fire protection service fire rescue division sector crew leader, having arrived to the accident site in the Strela-1 vehicle crew, after getting inside the aircraft they had seen one of the aircraft pilots (the PIC) in the front compartment, who reported the flight attendant, remaining on board, but had been unable to inform on the passengers, remaining on board. Inside the aircraft there had been the heavy smoke, high temperature and open fire. To move forward the fire extinguishing was proceeded with the use of the hand branch pipes.

At 15:42:43 the Gas and Smoke Protection Service second squad getting inside the aircraft, the extinguishing of the fire inside the fuselage and no fire outside the aircraft had been reported. The rescuer to the second squad communicated as well that by the point of getting inside the airplane there had been «a thick smoke».

In view of the stated in Section 1.16.18, most probably, by the point of the Gas and Smoke Protection Service employees there had been no survivors on board.

The fatally injured people had been retrieved after washing down of the cabin, the smoke dispersion in the progress of the removal of debris.

2.7.1. On the effect of the advance declaration of the Green code Alarm signal

Compliant to the Sheremetyevo International Airport, JSC Emergency Response Plan (ПЛ-2.3-02-15), in case the Alarm signal is declared of the Green code, the specific muster points are determined for the Air Operations Search Emergency and Rescue Support Service firefighting vehicles (Fig. 192):

– the northern terminal complex – at the front of the Runway Emergency and Rescue Station-1 (3 aerodrome vehicles out of the Runway Emergency and Rescue Station-1, 1 aerodrome vehicle and 1 Gas and Smoke Protection Service vehicle out of the Base Emergency and Rescue Station);

– the southern terminal complex – the A14 TWY (1 aerodrome vehicle out of the Runway Emergency and Rescue Station-2) and the 1A ramp (1 aerodrome vehicle out of the Runway Emergency and Rescue Station-2).

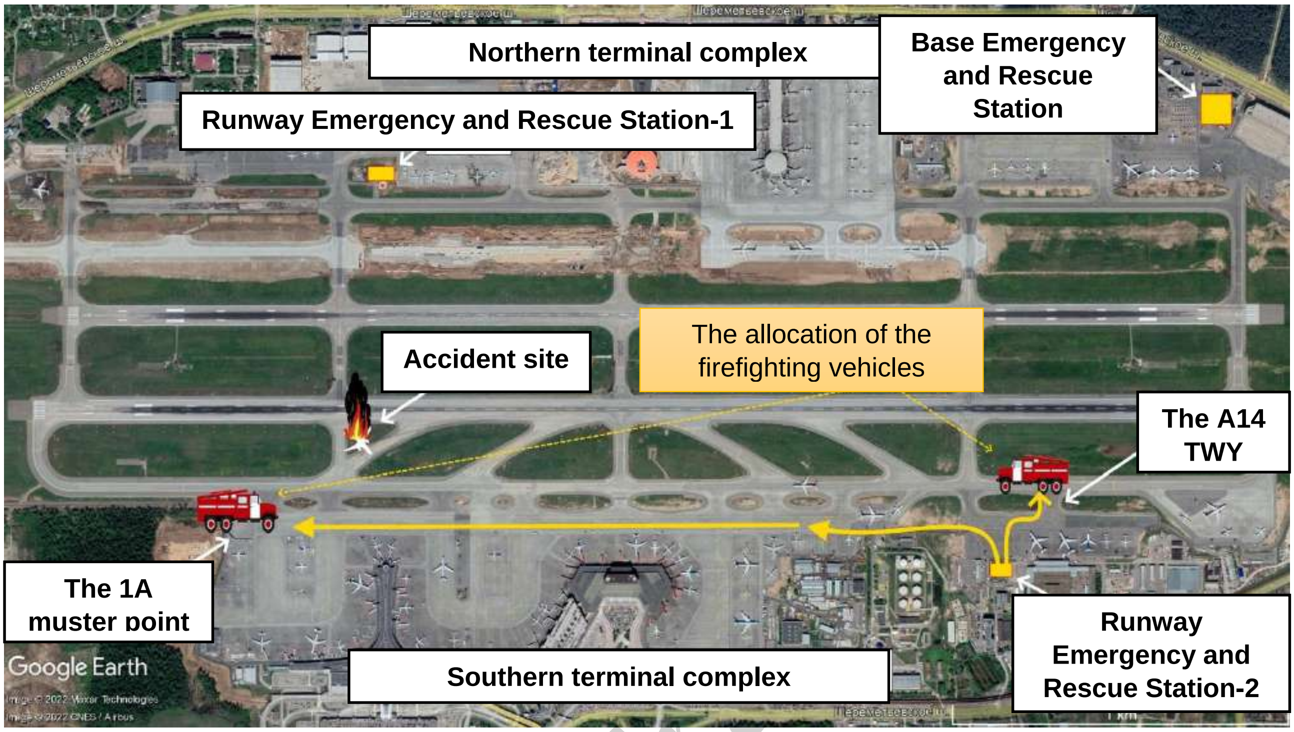


Fig. 192. The allocation of the Runway Emergency and Rescue Station-1, Runway Emergency and Rescue Station-2, Base Emergency and Rescue Station emergency and rescue teams routes and muster points by the Green code Alarm signal at Sheremetyevo aerodrome

On the arrival to the muster point the vehicles shall stand by with the engines running.

In this way, in the event of accomplishment of the firefighting vehicles gathering by the Green code, the firefighting vehicle at the 1A ramp would have been the closest to the RRJ-95B RA-89098 aircraft stop point. It would have arrived to the accident site in about 20 sec. (40–45 sec. earlier against the actually accomplished time), whereas the time of arrival of the next vehicles from the other muster points would have decreased by 40-50 sec. against the actually accomplished time.

It can be asserted that the earlier arrival of the firefighting vehicles would not have altered the tactics of the fire extinguishment: the foam attack first, followed by the wash-down with the hand branch pipes and Gas and Smoke Protection Service squads getting inside the aircraft. Likewise the earlier arrival of the firefighting vehicles would not have ruled out the penetration of fire inside the passenger cabin, therefore, in view of the stated in Section 1.16.18 of the Report, there is no way to objectively evaluate its possible effect on the severity of consequences.

3. Conclusion[208]

The air accident to the RRJ-95B RA-89098 aircraft was caused by the uncoordinated control inputs by the PIC at the flare, landing and through the several repeated bounces of the aircraft off the RWY (the porpoising), having manifested in the several disproportionate alternating sidestick inputs in pitch with keeping the sidestick retained against each stop. The indicated control inputs had resulted in three hard touchdowns of the aircraft, as a consequence at the second and third touchdowns the absorbed energy significantly exceeded the maximum values, for which the structural integrity had been evaluated at the aircraft type certification, which led to the destruction of the airframe structural elements, the fuel tanks with the fuel spillage and the fire onset.

The contributing factors to the accident were[209]:

– the ineffectiveness of the RRJ-95 flight personnel approved training programs as for the actions into the major failure condition//abnormal situation at the FBWCS reversion to DIRECT MODE and, consequently, the insufficient knowledge and skills at the flight crewmembers to operate the airplane in this mode. The training programs met the minimum requirements, determined by FAR, but did not account for the specific nature of a particular emergency;

– the ineffectiveness of the airline SMS in terms of the monitoring of the piloting sustainable skills development at the pilots, which prevented the identification and elimination of the PIC's common systematic errors at the sidestick pitch control at the stage of landing, including these, associated with its forward inputs beyond neutral (to nose down) into the flare;

– the failure to identify the biases (hazards) in the airline flight crews' piloting technique as far the previous events of the FBWCS reversion to DIRECT MODE are concerned and thus the failure to implement preventive measures;

– the aircraft operational documentation unclear wording in terms of the piloting peculiarities at flare and the correction of the deviations at the landing (counteracting the consecutive aircraft separations off the RWY);

– the failure of the crew to comply to the FAR and OM requirements at the flight preparation and performance at the actual and forecast thunderstorm activity, as well as at the availability to observe these zones on the weather radar display, which had resulted in the aircraft encounter the atmospheric electricity, the EIUs reboot and the FBWCS reversion to DIRECT MODE. As per the certification results the FBWCS reversion to DIRECT MODE had been

[208] Compliant with Annex 13 to the Convention on International Civil Aviation «Aircraft Accident and Incident Investigation», the determination of the causes and/or contributing factors to the accident *«is not to apportion blame or liability»*.

[209]In compliance with Manual of Aircraft Accident and Incident Investigation (ICAO Doc 9756 FN/965), the contributing factors are stated in the chronological sequence irrespective of their priority assessment.

assessed as «the major failure condition», the in-flight onset of «the major failure condition» at the lightning or static electricity exposure does not contradict the applicable certification requirements;

– the dramatic increase of the psychoemotional stress at the PIC because of the aircraft exposure to atmospheric electricity and the failure within a long time to ensure the acceptable piloting precision at the FBWCS in DIRECT MODE, which led to the psychological dominant mindset formation to perform immediate landing together with the lack of readiness to initiate go-around (not go-around minded);

– psychological personality traits of the flight crewmembers that determine their behavior in the stress environment, as well as the PIC's insufficient training in human factor/performance and threat and error management approach, which prevented the objective assessment of his psychoemotional condition and the ability to control the airplane, to choose the optimal strategy to proceed the flight, as well as to establish the required interaction and CRM;

– the failure of the PIC to ensure the aircraft pitch trim under the manual control, including at the glideslope descent;

– the incorrect assessment of the situation by the crew at the Predictive Windshear warning (GO AROUND WINDSHEAR AHEAD) trigger at the flight on glideslope and, consequently, the non-initiation of a go-around maneuver, that resulted in the aircraft encounter the wind microburst at the early flare and affected the aircraft flight path. The documentation by the aircraft designer and the airline allows the crew to ignore the subject warning activation, if it made sure there is *«no windshear threat»,* still the operational documentation and the OM do not integrate the respective clear criteria of *«no threat»*;

– the purposeful ducking under the glideslope by the PIC at the final approach (after passing DH);

– the difference between the airline OM provisions as for the crew actions at the glideslope warning activation (the excessive deviation off the glideslope equisignal zone) and the similar provisions in the aircraft designer documentation. Subject to the provisions of the aircraft designer documentation the crew should have performed go-around;

– the unjustified extension by the airline of the approach «stabilized condition» criteria as for the acceptable deviations range off the target speed, which at the actual IAS of 15 kt higher against the target one and the FBWCS in DIRECT MODE resulted in the unexpected for the PIC increased aircraft response to the sidestick input in pitch;

– the failure by the crew to carry out the SOP on the manual speedbrakes deployment at the aircraft touchdown. The operational documentation unclear wording and the monitoring algorithms of the landing configuration, used at the aircraft that require to arm the speedbrakes for the automatic deployment, including at FBWCS in DIRECT MODE, in which the automatic deployment is disabled, degrade the crew's situational awareness as for this aspect.

– the TR actuation after the first bounce off the RWY, which had made the subsequent go-around impossible.

As per the results of the forensic medical examination the death of 40 out of 41 fatally injured people had been caused by the exposure to open flame, accompanied with the burns of the upper respiratory tract through the inhalation of hot air.

The fire erupted after the aircraft third touchdown due to the disintegration of the wing fuel tanks and the fuel spillage. The fuel spillage occurred as due to the destruction at the landing gear retraction/extension actuating cylinders attachment points, as well as due to the destruction of the other wing parts. The landing gear structure had been damaged at the second touchdown that is at the third touchdown functioned beyond the expected operational conditions and had not been able to bear the applied landing loads as designed.

The operation (destruction) of the landing gear fuse pins («weak links») at the second touchdown had been consistent with the design integrated logic. With that the loads, actually accomplished, had been less of those in use to demonstrate compliance to AR-25 item 25.721 at the aircraft type certification, which prevented the MLG legs to completely separate off the airplane structure (it is only the Attachment A fuse pins that had been destructed). No correlation between the certification requirements for the structure, including MLG legs structure, and the conditions for demonstrating their safe separation off results in actual significant risks of the fuel tanks disintegration and the fuel spillage even in case of compliance demonstration to every single of these requirements.

At its very onset the fire by its nature had been the deflagration flash[210], which had been accompanied with an intense smoke release with the onset of a steady burning in two seconds. By the point of the evacuation initiation the fire had been propagated inside the cabin through a row of cabin windows at the rear fuselage along the right and left sides, with that the airworthiness standards do not set up the requirements for the cabin windows as to the external fire protection. That situation had been beyond the expected operational conditions as there had been no time margin (90 sec), at which the crew and passengers' emergency evacuation is demonstrated at the type certification.

Most probably the following factors had contributed to the increase in the severity of the consequences:

[210] Deflagration is a propagation of flame through a combustible mixture, occurring by diffusion of active sites and heat transfer from the flame front to the unburnt mixture.

- the running engines of the aircraft, having been not timely shut down by the crew;
- large amount of fuel, spilling out of both wing panels, which penetrated the area of the exhaust-mixing nozzles, exposed directly to their jet streams;
- the inability to evacuate through both of the rear emergency exits;
- the manifestation of the flashover effect at the rear passenger cabin;
- the crush and panic among the passengers;
- the efforts by a number of passengers to pick up their carry-on luggage at the evacuation;
- the CFA's error in operating the PACIS, and consequently the decline in the passengers' situational awareness as for the evacuation procedure.

The simulation of the fire development by the Russia EMERCOM Saint Petersburg State Firefighting Service University, FSEI HE had revealed that the flight attendant's erroneous actions to having opened the left rear door in that actual environment had not led to the increase of the fire destructive factors magnitude and had not affected the accident outcome.

4. Other shortcomings, revealed in the investigation[211]

4.1. The USSR Civil Aviation Air Operations Search and Emergency Rescue Support Manual-91, having been in effect on the date of the air accident as for several items contains less stringent requirements on the emergency rescue response procedure against these recommended by the ICAO Doc 9137 Airport Services Manual Part 1- Rescue and Firefighting; Fourth Edition, 2015.

4.2. The USSR Civil Aviation Air Operations Search and Emergency Rescue Support Manual-91 item 3.27 and ICAO Annex 13 determine the response time of arrival on the accident site of the first emergency rescue team crew of three minutes from the point of the declared Alarm and of four minutes from the point of Alarm, declared to the firefighting rescue crews up to the point of the initiation of discharge of the fire suppressant for the next of the crews. ICAO Doc 2.7.1 (Part 1) recommends this time being *«of two minutes and not exceeding three minutes»*.

4.3. ICAO Doc 9137 (Part 1) introduces the tenth category for rescue and firefighting level of protection, whereas the USSR Civil Aviation Air Operations Search and Emergency Rescue Support Manual-91 only integrates nine categories with no account for the operation of the airplanes with the over-all length of more than 76 m. Thus the USSR Civil Aviation Air Operations Search and Emergency Rescue Support Manual-91 does not contain the standards of the extinguishing agents reserve supply and the aerodrome firefighting vehicles performance that would correspond to the tenth category.

[211] The Section presents the shortcomings that had been revealed throughout the investigation, but had not been subject to analysis through the text of the Final Report.

5. Safety Recommendations and associated Safety Actions [212]

5.1. Safety Actions

5.1.1. In the progress of the investigation the Aircraft Operations Emergency Rescue Support FAR have been brought into force (approved by the Ministry of Transport Order # 517 of November 26, 2020).

5.2. Safety Recommendations

It is recommended that FATA[213]

5.2.1. Brief the civil aviation air personnel on the results of the fatal air accident investigation to the RRJ-95B RA-89098 aircraft.

5.2.2. Consider practicability of establishing requirements for the proficiency and the introduction of the examiner rating, as well as the requirements on the mandatory conduct of all the qualification checks and checks to authorize for flights performance by the independent pilots, having been assigned the rating in question and accredited by the aviation authorities and not by the flight instructors to the airline itself (this Safety Recommendation is here reissued).

5.2.3. Consider practicability of introducing amendments to FAR-128 to ensure the flight personnel recurrent training in extended expected operational conditions (Section 1.18.13 of the Report).

5.2.4. Consider practicability of introducing amendments to FAR-128 to ensure mandatory recording and storage of the flight data at the pilots' simulator proficiency checks, for instance by introducing requirements on the data recording by voice and data recorders, similar to FDR and CVR or by video cameras.

5.2.5. In association with the aircraft designers consider practicability of creating lists (as per the aircraft types) of the emergencies and abnormal situations, subject to the mandatory «individual» practicing, with its recurrent update based on the risk assessment and synthesis of the operational experience, as well as of model scenarios to practice these situations.

5.2.6. As to the certified aircraft types, review the appropriateness of the introduction of a special section to the TCDS (in a similar manner to the EASA Operation Suitability Data), defining inter alia for the specific aircraft type, the areas of training of the flight and cabin

[212] In compliance with ICAO Annex 13 to the Convention on international civil aviation «Aircraft Accident and Incident Investigation» the Safety Recommendation is *«a proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident»*.

[213] It is recommended that the aviation authorities of the participant states to the Agreement consider the applicability of the Safety Recommendations based on the actual state of affairs as for them.

crewmembers that require increased attention (similarly to the EASA Training Areas of Special Emphasis).

5.2.7. Develop and implement methods for assessing compliance to the airworthiness standards (aviation regulations).

5.2.8. Consider practicability of introducing the unified drill assignment form to be filled in at the practice of the in-flight emergencies and abnormal situations.

5.2.9. Analyze the content of the Civil Flight and ATC Personnel Selection, Training and Professional Activities Psychological Support Manual to ensure its compliance to modern psychological knowledge, including in terms of sufficiency of the methods, used to identify the pilots' personality in relation to the way of emotional response and behavior in emergencies (this Safety Recommendation is here reissued).

5.2.10. Consider practicability of introducing requirements on the air personnel psychological testing performance by the independent psychologists only and not by the airlines' own medical centers with the mandatory application of the MMPI method.

5.2.11. In view of the systematically identified irregularities in compliance to the flight personnel work and rest schedule pay particular attention to this issue at the audits of the airlines, develop and implement the set of systematic measures to eliminate the subject hazard (this Safety Recommendation is here reissued).

5.2.12. Specify FAR on the procedure of conducting recurrent proficiency checks of the flight and cabin crewmembers, authorized to perform flights aboard several aircraft types.

5.2.13. Introduce amendments to Air Operations Regulations in part of specifying the criteria of setting international squawk emergency codes and the procedure for their removal, as well as on the actions of the flight and ATC personnel in these cases.

It is recommended that FATA, IAC AR, EASA and the other aircraft certification authorities

5.2.14. Given the results of the subject investigation assess the sufficiency of the current requirements on the aircraft protection against the fire propagation inside the fuselage at the onset of the external fire. As per the assessment results make the decision on the necessity to establish additional requirements to the protection of the cabin windows and the other aircraft elements.

5.2.15. In view of the results of the subject investigation assess the mutual consistency of the established requirements on the time interval, for which the aircraft emergency evacuation and the arrival of the first aerodrome firefighting vehicle at the air accident occurrence at the aerodrome shall be demonstrated (90 sec / 180 sec). On the results of the assessment make decision on the necessity of refinement of the current requirements.

5.2.16. Subject to the results of the present investigation consider practicability of harmonization (establishing correlation) of the airworthiness standards provisions that determine requirements to the MLG structural integrity and demonstration of their safe separation. Develop and implement the methods of the compliance demonstration as per Aviation Regulations item 25.721, integrating clear criteria on the value of the loads, at which the MLG safe separation shall be demonstrated.

5.2.17. Consider practicability of complementing the aviation regulations (airworthiness standards) with the requirements on the alert megaphones allocation on the aircraft in a way that the access to them would not complicate the emergency evacuation process.

5.2.18. Consider practicability of the use of the smoke hoods/PBE and/or the other protective devices by the cabin crew into the certain scenarios of emergency evacuation.

5.2.19. Consider practicability of introducing the certification requirements on the mandatory installation of the video cameras at the flight deck with the information recording to crash-resistant recorders (in the event of the potential air accident).

It is recommended that Aeroflot, PJSC[214]

5.2.20. Within the functioning of the SMS audit the methods in use for identification of the hazards and monitoring of the relevant risks, with special focus on the necessity of the proactive and predictive approaches.

5.2.21. Within the functioning of the SMS arrange for the thorough documenting of every pilot's actual amount of training, including comments by the flight instructor personnel. If there are any comments, save the evidence (the records by the data recorders, video records, etc.).

5.2.22. Through the functioning of the SMS develop and implement measures on the routine monitoring of every pilot's piloting technique as per the recorders data along with the identification of hazards (negative trends) and monitoring of the associated risks.

5.2.23. Develop and implement set of measures that would preclude the non-compliance to the OM provisions at the flight personnel training. Emphasize the fulfillment of the requirements on the flight instructor personnel assignment to the trainee and the increase of personal responsibility of the assigned flight instructor for the training outcome

5.2.24. Consider practicability of the one-time psychological testing conduct of the flight personnel by the independent psychologists with the mandatory application of the MMPI method.

[214] It is recommended that other airlines consider practicability of implementing these Safety Recommendations subject to the actual state of affairs.

5.2.25. Consider practicability of the increase in the staffing and the level of competence for compliance to the occupied post for the psychologists, employed at the airline medical center.

5.2.26. Reassess the risks, associated with the difference between the OM provisions and similar provisions of the aircraft operational documentation in terms of establishing the stabilized approach criteria and the crew actions at the activation of the glideslope warning.

5.2.27. In association with the aircraft designer reassess the risks, related to the potential ignorance of the Predictive Windshear Warning by the crews. At the preserving of the possibility of ignorance introduce a comprehensive list of the criteria, confirming the potential presence of windshear to the OM.

5.2.28. Arrange additional training to the flight and cabin personnel (by the aircraft types) on the actions at the emergency evacuation. Emphasize the procedure of communication between the flight and cabin crewmembers with each other and the passengers, as well as the specific features of the evacuation at the onset of fire.

5.2.29. Develop the model criteria of decision-making on the landing with the exceeded maximum landing weight with the inclusion in the airline OM.

5.2.30. Arrange additional training to the flight personnel:

- on the procedure of use of the aircraft weather radars, as well as on the air operations into thunderstorm activity and heavy shower rains;
- on the prevention of hard landings;
- on the reasons for the occurrence of the bouncing effect, as well as on the strategies of its avoidance and counteract.
- on the procedure of setting and removal of the international emergency squawk codes and the interaction with the ATS on this matter;
- on the human factor impact on the aviation safety, as well as on the threat and error management methods. Emphasize the recognition of the signs of the situation, going beyond human capacity, that is the signs of the psychological incapacitation;
- on the QRH procedures performance with the focus on the interaction in the crew and CRM.

5.2.31. Develop and implement the set of measures, precluding non-compliance to the flight personnel work and rest schedule.

It is recommended that the RRJ-95 aircraft operators

5.2.32. Assisted by the aircraft designer conduct additional training to the flight personnel on the features of operation in the FBWCS DIRECT MODE, focusing in particular on the change of the flight environment, in which the aircraft manual trim in pitch is required, as well as on the common errors at the aircraft flare and landing (see Section 1.16.19 of the Report).

5.2.33. Consider practicability of the increase in amount of the simulator training at the operation of the FBWCS in DIRECT MODE through all the legs of the flight, including go-around. Consider the applicability of this Recommendation to other aircraft types in operation.

5.2.34. In light of shortcomings, having been identified as far as the PIC's piloting technique is concerned at the flare, landing roll and takeoff run carry out a statistical analysis of these elements performance at all RRJ-95 pilots. Undertake the respective corrective measures, as appropriate. Consider applicability of this Safety Recommendation to the other aircraft types.

5.2.35. In association with the aircraft designer assess the accuracy of functioning of the tools, engaged in the CG values estimation.

It is recommended that the RRJ-95 aircraft designer

5.2.36. In cooperation with the certification authorities consider practicability of introducing amendments to the landing gear design and/or introducing equivalent measures to mitigate the risk of the fuel spillage occurrence at the MLG legs destruction. As for the assessment use international practice as for the criteria of «sufficient volume» of the fuel spillage to cause a fire hazard. On the results of the assessment make decision on a further development of the newly manufactured airplanes and/or these in operation (the Safety Recommendation is here reissued).

5.2.37. In association with the certification authorities analyze the available international experience and consider practicability of the redesign and/or the amendment of the operational procedures to ensure the cabin crew's availability to use the PACIS inside the passenger cabin at the passenger evacuation.

5.2.38. In association with the certification authorities consider whether additional measures should be taken to reduce the incidence (operational probability) of the FBWCS reversion to DIRECT MODE.

5.2.39. Arrange the one-time check (the proofreading) of the AFM, FCOM, FCTM and other documents to eliminate errors and inaccuracies. Considering the stated in Section 1.18.27 of the Report, introduce amendments and additions to the bulletins, intended for the flight personnel (this Safety Recommendation is here reissued).

5.2.40. Review the flight crewmembers' performance on the processing of a considerable number of failure messages that may annunciate in flight, for instance due to the EIUs reboot. When appropriate take measures on the reduction in the number of the annunciated messages.

5.2.41. Reassess the risks, associated with the potential ignorance by the crews of the predictive windshear warning. At the maintaining of the possibility of ignoring introduce a comprehensive list of criteria, confirming the potential presence of windshear, to the operational documentation.

5.2.42. Consider the potential of the in-flight restoration of serviceability of the FBWCS NORMAL MODE at the functional resumption of the aircraft equipment.

5.2.43. Consider possibility to ensure the automatic deployment of the speedbrakes at touchdown at the FBWCS in DIRECT MODE. In case of impossibility clearly determine the procedure and sequence of the speedbrakes and reverser actuation at touchdown.

5.2.44. Consider changing the allocation point of the megaphone or the design of the closet at the front entrance area to ensure the free use of the megaphone into the emergency passenger evacuation. Consider allocating a second megaphone in the tail section of the aircraft.

5.2.45. In view of the data, set out in Section 1.18.31 of the Report, consider practicability of amending the procedure for using the sidestick into the takeoff run and landing roll, as well as its position monitoring.

It is recommended that State Air Traffic Management Corporation, FSUE

5.2.46. Consider amending of the ATC centers' officers SOP in terms of determining of the actions by the ATC personnel at the issuance of the international emergency codes by the flight crews without declaring them at the radio contact.

5.2.47. Arrange additional training to the ATC personnel

- on the features of the ATC into actual occurrence of the significant meteorology;
- on the criteria of declaration of the Alarm signals.
- on the rules for the aircraft vectoring and the features of the radio communication conduct on the operating and emergency frequencies at once.

5.2.48. In cooperation with the ATC automation equipment manufacturers arrange further development of the software in terms of increasing awareness and drawing attention of the ATC personnel at the issuance of international emergency codes by the aircraft flight crews and their display at the aircraft data block. At the impossibility of the further development undertake additional measures, mitigating the risk of the overlooked issuance of the squawk emergency code by the flight crew.

5.2.49. Eliminate inconsistencies in the terminology and determination of the control areas boundaries and the control transfer lines at the ATC officers SOP, highlighted through the text of the Report.